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Smokes and Obscurants: A Guidebook of Environmental Assessment

Volume II. A Sample Environmental Assessment

Joseph H. Shinn
Laurel Sharmer
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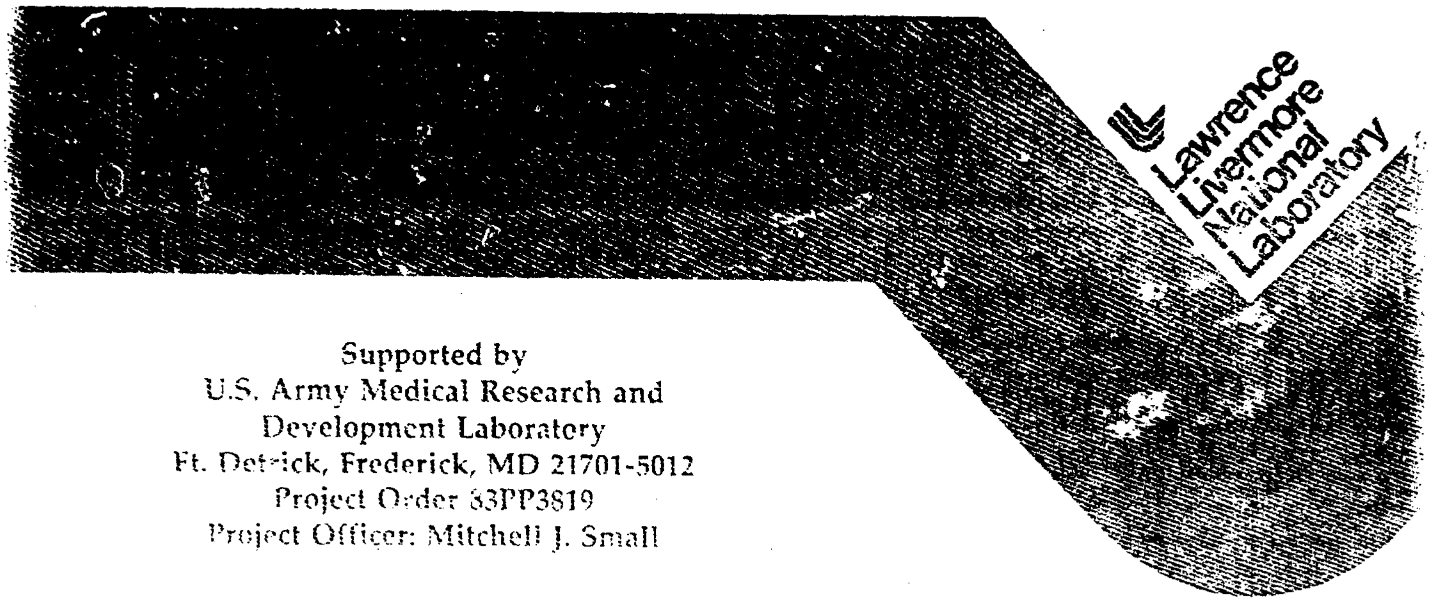
September 4, 1987



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Environmental assessments (EAs) are one type of document that can be required prior to the authorization of field tests of smokes and obscurants; EAs are documents that are written to comply with the National Environmental Policy Act (NEPA). This guidebook was prepared to facilitate the preparation of EAs for field tests of smokes and obscurants. The guidebook is divided into two volumes: Volume I--Method of Assessment and Appended Data, and Volume II--A Sample Environmental Assessment. This volume (Volume II) presents the thirteen major sections of a sample environmental assessment through the use of explanatory material and hypothetical text. The major sections are (1) an introduction, (2) a statement of the proposed action, (3) a description of the environmental setting, (4) a discussion of the physical, chemical, and biological properties of the smokes and obscurants being tested, (5) a discussion of impact criteria, (6) an identification of environmental effects, (7) a consideration of environmental consequences, (8) a discussion of the cumulative, long-term effects of repeated tests, (9) a discussion of short-term effects versus effects on long-term productivity, (10) a statement of recommended alternatives, (11) a consideration of mitigation, (12) recommendations for the next step in the NEPA process, and (13) references.

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Volume II. A Sample Environmental Assessment

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CONTENTS

SMOKES AND OBSCURANTS:

A GUIDEBOOK FOR ENVIRONMENTAL ASSESSMENT

VOLUME II. A SAMPLE ENVIRONMENTAL ASSESSMENT

This volume is designed to help guide the user through the preparation of an Environmental Assessment (EA) based on the use of smokes and obscurants (S&O) in Army field tests. This sample EA will not be as thorough and complete as an actual EA would be. It will use hypothetical examples only and will informally introduce the user to the process of writing an EA.

Each section of the sample EA will have a brief explanation or description of the topic in an EA (which will be presented in this typeface) and then will be followed by an example of what that section would look like in an actual EA (which will be presented using narrower margins in a bold typeface). It will be important to keep in mind that this sample was written for a sparsely populated desert area and many actual test sites will be vastly different from the hypothetical site used here.

Most of the references cited in the text of the sample EA, although actual scientific studies, will not be listed in the references section because the sample part of the document has not been prepared for an actual site.

I. INTRODUCTION

The Environmental Assessment will begin with a concise introduction. The introduction provides background information about S&O, the site, and any special legal or environmental considerations. It will also briefly state the area of the test or training, the type of smoke being used, and the reasons for conducting the tests or training.

I. INTRODUCTION

In the modern military, smokes have a variety of applications. Man-made smoke, when properly employed as a passive defense, can significantly

influence the tactical operations of both friendly and enemy forces. Smoke may be used for obscuration, screening, deception, and identificaton.

During the 1973 Yom Kippur War, the use of smoke for tactical operations was given much attention. In this conflict, the use of smokes and obscurants played a large role in reducing the effectiveness of antitank guided missiles against armored assaults.

The US Army Training and Doctrine Command (TRADOC) has developed an operational concept for the employment of smoke and smoke countermeasures. Troops are being trained in the tactical use of smoke and to operate in areas of low visibility.

This EA is written for the field testing of white phosphorus smoke in felt wedges at Devil's Washbasin, a hypothetical Army installation in a desert area of the United States. The environmental consequences of testing phosphorus smoke in this area are examined, and mitigations and recommendations are developed that will protect the area's natural resources and reduce land use impacts.

Guidelines for preparing this EA are in Army Regulation 200-2. The office of the Chief of Engineers at Devil's Washbasin is the lead office in the preparation of the document.

All guidelines and restrictions concerning the testing of phosphorus smoke determined by the Department of the Army have been applied. It is assumed that the tests will be used in a manner so as not to introduce persistent, cumulative contaminants into the environment, and that there will be sufficient time between each test for the recovery of natural resources.

Geographic limits to downwind concentrations of smokes are determined by modeling conducted using HAZRD2 (a gas-dispersion model), meteorological data, and previous tests. The limits and testing impacts are discussed as worst-case scenarios. The actual tests, however, will begin on a small scale until the initial impacts can be evaluated.

II. PURPOSE OF PROPOSED ACTION

A. PROPOSED ACTION

This statement of the proposed action should begin with the purpose of

the test or training and the reason for implementation. The methods and procedures should be described.

II. PURPOSE OF PROPOSED ACTION

A. PROPOSED ACTION

Phosphorus smokes are important on the modern battlefield in screening and obscuring friendly operations from the enemy. White phosphorus is highly reactive with oxygen. Because of this, it is used to advantage in bursting munitions such as mortar rounds, artillery, and grenades. This same property, however, can present a hazard to personnel. It is, therefore, necessary to handle it with caution.

To support a tactical plan, troops at the Devil's Washbasin site are being trained in the use of smoke screens to cover a designated target or area. Of greatest importance in the testing are the size of the area to be covered, the nature of the terrain, and the meteorological conditions.

The trainees are presented with smoke training exercises: an area to be covered and the duration of coverage. Then, under the supervision of instructors, the trainees plan and implement the operation. Any one training exercise will generally require the production of smoke for a period of one hour. The smoke used will be white phosphorus/felt wedges (WP/FW). As the test continues, the instructors make careful observations of the smoke cloud and meteorological conditions, and will terminate the exercise if it appears that the smoke cloud is likely to travel outside of the designated area.

B. TEST DESCRIPTION

It will be necessary to summarize the processes of the tests. The handling, transportation, preparation, and operation of the smoke products should be defined.

An estimate for the degree of impact can be made using tables in Volume I. For example, assume for our purposes that the fictitious Devil's Washbasin has the same weather as Fort Benning. Look at Table 16 in Volume I, which lists the devices, and find that the maximum airborne concentration (MAC) for the M2 munition is given as 3100 mg/m^3 and the minimum area of

impact (A) is 516 m^2. Conceptionally, the MAC is the average concentration within the plume above the Area A. Note also from Table 18 that the inhalation toxicity (LC_{50}) of WP is 2500 mg/m^3. Because the MAC exceeds the LC_{50}, all personnel should be excluded from the area (A) and an adequate safety zone beyond it. We estimate the significant impact zone as defined by the distance to 1% of the LC_{50}. This is identified as the interim threshold value (ITV); a cursory analysis (Shinn et al., 1987) of the ratios of recommended short-term exposure limits (STEL) to LC_{50}s indicated that most ratios were less than 1:100. On the average, an ITV should tend to underestimate an STEL. The table shows that for Fort Benning in summer the stability-category frequency, median wind speed, and median mixing depth occur as follows (values for winter, fall, and spring are similarly determined).

Stability Category	Frequency %	Median Wind Speed (m/s)	Median Mixing Depth (m)
A	8.3	1.1	1654
C	17.9	1.7	1417
D	17.3	2.2	810
F	36.1	0	304

The charts in Appendix C for the munition M2 show that for stability Category A (very unstable) and wind speed 1.1 m/s, the downwind distance to the ITV is estimated at 0.3 km for all mixing depths over 200 m. Likewise, the listed stability Categories C and D for the median wind speeds have ITV distance estimates of 0.7 km and 1.0 km, respectively. The stability Category F (stable) is a special problem because zero wind speed (calm) is the median wind condition in summer. We see that the M2 munition chart shows a downwind range to the ITV at wind speed 1.0 m/s is 7.5 km or greater. Lesser wind speeds could produce even greater distances, but worse yet, calm winds cause meandering and unpredictability of the smoke direction. So even though it occurs the most frequently, stability Category F is to be avoided as a smoke release period. Smoke release during stability Categories C and D could be recommended if tests are restricted to conditions when wind speeds exceed 1 m/s, under these conditions the median winds would produce distance to ITV of 1 km or less. Safety factors of not less than a factor of two for smoke release in remote areas and not less than a factor of ten for public roads or inhabited areas should be followed. Therefore, test descriptions should be written conservatively.

B. TEST DESCRIPTION

The geographic limits for the smoke training exercises to be held at Devil's Washbasin are an area of 247 acres. The site is a normally dry lake bed (Devil's Washbasin). Downwind meteorological data and downwind smoke concentration levels will be monitored and recorded to insure that hazardous concentrations of smoke are contained in the geographic area.

Each M2 munition will produce a smoke plume estimated to reach an environmentally significant concentration at less than 1 km downwind during stability Categories C and D. Either of these stabilities may occur greater than 35% of the time and have the strongest winds of all stability classes. The reference environmentally significant concentration is 25 mg/m^3. This value is 1% of the estimated lethal concentration for 50% of rats exposed for 1 hour (LC_{50}). This concentration is also about one-tenth the amount needed to restrict visibility. No TLV-Short Term Exposure Limit (TLV-STEL) has been established for white phosphorus smoke. Except for Category A in fall and winter, stability Categories A and B with median wind speeds or greater are also adequate to disperse the plume within 1 km. For an added margin of safety, all personnel will be excluded within 2 km and all tests will be conducted more than 10 km from the public roads and habitations. No permanently occupied buildings or living quarters exist within 10 km of the proposed site. Highway 47 is 30 km to the east of the proposed site.

Multiple-shot smoke exercises will also be conducted in an environmentally sound manner because the rate of M2 deployment is commensurate with the advection due to wind. At a wind speed of 1 m/s, it will take 1000 seconds for the smoke from one shot to clear 1 km. Under these conditions, repetition of M2 munition deployment is necessary to maintain the smoke screen. The actual rate could be varied from one per 500 seconds to one per 50 seconds depending on wind speed, but the goal to maintain the concentration for 1 hour would be the same. It is not desirable either from an environmental standpoint or from an economic standpoint to exceed the reference concentration by overuse of munitions.

The frequency of smoke production will be one hour per week for 52 weeks a year. The minimum area of impact for this bursting munition is about 516 m^2. The average concentration in the plume volume over this area

is estimated to be 3100 mg/m^3. The rate of munition deployment will be sufficient to maintain this concentration and will range from 7 to 72 per hour. The concentration of 25 mg/m^3 will not be exceeded at a distance of 1 km downwind; nonetheless, margins of safety include the exclusion of personnel 2 km downwind and prohibition of testing within 10 km of a public road or habitation.

An array of diagnostic sensors will be placed up to 16 km downwind of the ignition site to obtain cloud dispersion data (Fig. 1). Wind speed and wind direction will be monitored by 2 anemometer stations. A photographic and meteorological tower will be contained in the array, as will 40 sensor stations, to enable collection of data from a large variety of sensors at various levels above ground. These sensors will be used to measure smoke concentration, humidity, heat flux, aerosol characteristics, and turbulence.

III. THE ENVIRONMENTAL SETTING

The different ecological factors that make up the environment of the test area are all related in a system of complex interdependence. The EA should be written so that it will be possible to understand all of the interrelationships of this ecological community before the implementation of the smoke tests. The existing ecological community then acts as a control and establishes a norm by which it is possible to evaluate the impacts of the tests on the area.

The first part of the environmental setting is a brief general description of the actual site.

III. THE ENVIRONMENTAL SETTING

A. PHYSICAL FACTORS

1. General Description

Devil's Washbasin is an alluvial desert basin located on the south side of a military installation in the Western United States. The western boundary of

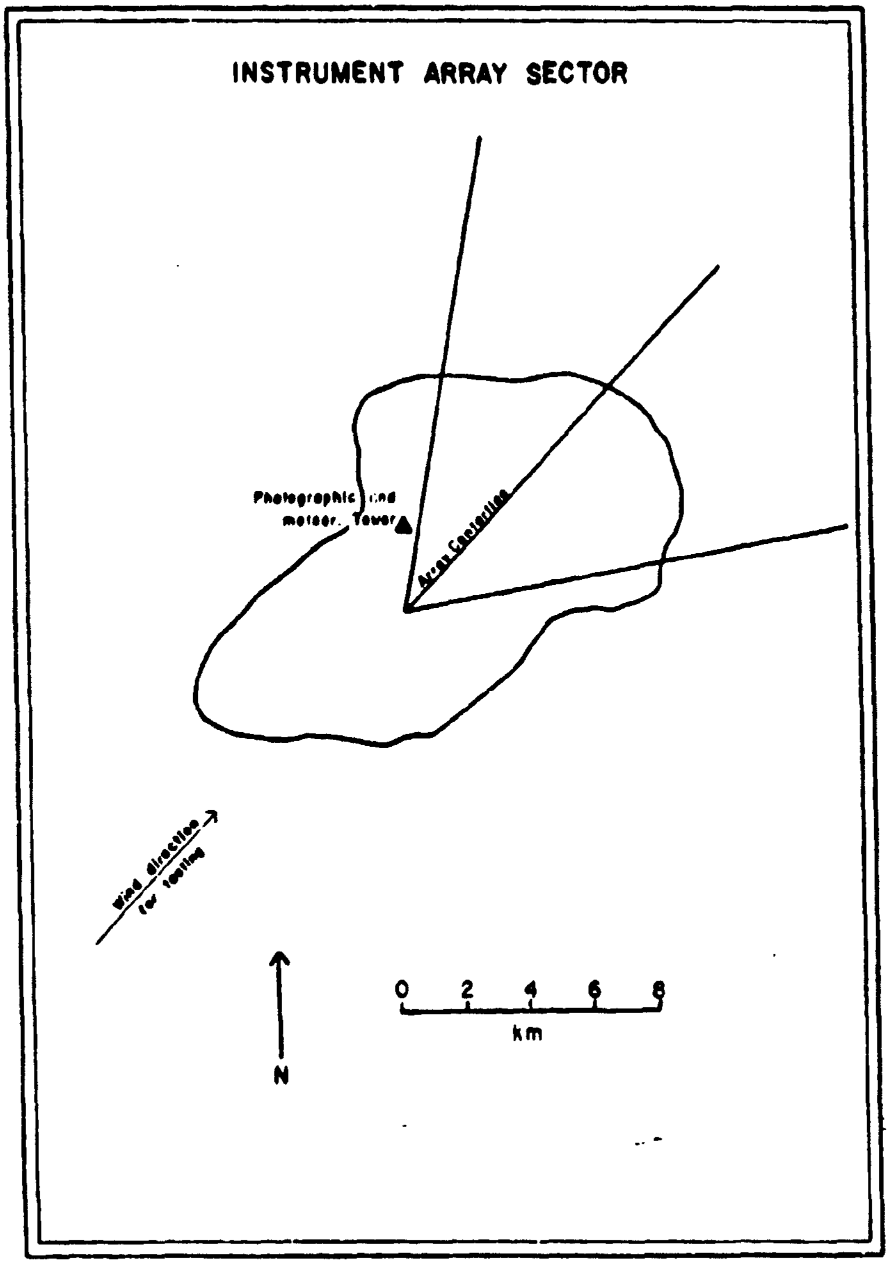

Figure 1. Instrument array sector on playa at Devil's Washbasin.

the Western Regional Wildlife Range (WRWR) is 5 km east of the installation boundary. The US Department of the Interior, Fish and Wildlife Service, is currently conducting a wilderness review in this area.

Devil's Washbasin is located 90 km northeast of the town of Wildwood and is 120 km south of the city of Grand Island (Fig. 2). Highway 47 is the main north-south access road in the area. The region is sparsely populated and the main economic activities are ranching and mining. The community closest to this area is the town of Buffalo (pop. 422), 75 km to the south.

Devil's Washbasin has been used in the past for smoke tests. The area is currently being used for ammunition testing and non-nuclear explosives testing. Some Air Force bombing and gunnery tests also take place here (Fig. 3). The large desert areas to the southeast and west of the installation have been used in the past for mining, farming, and grazing.

2. Air Quality

In writing an EA for smokes and obscurants, it should be obvious that one of the most important impacts that the test procedures will have on the environment will be the impact on the air.

There are a number of steps that need to be followed to evaluate the ambient air of the test site and to predict the impact that testing will have on the air quality. The first step is to describe the history and importance of air pollution control in narrative form.

2. Air Quality

The federal Clean Air Act of 1977 (CAA) established a program for the creation of air quality standards. This program was established because of public concern about the health aspects of air pollution.

The CAA has been amended to establish National Primary and Secondary Ambient Air Quality Standards (NAAQS) in order to control particular criteria air pollutants and to protect human health and the environment. Ambient air is defined by the CAA as the portion of the atmosphere that is external to buildings to which the general public has access. Primary standards protect human health and secondary standards protect human welfare.

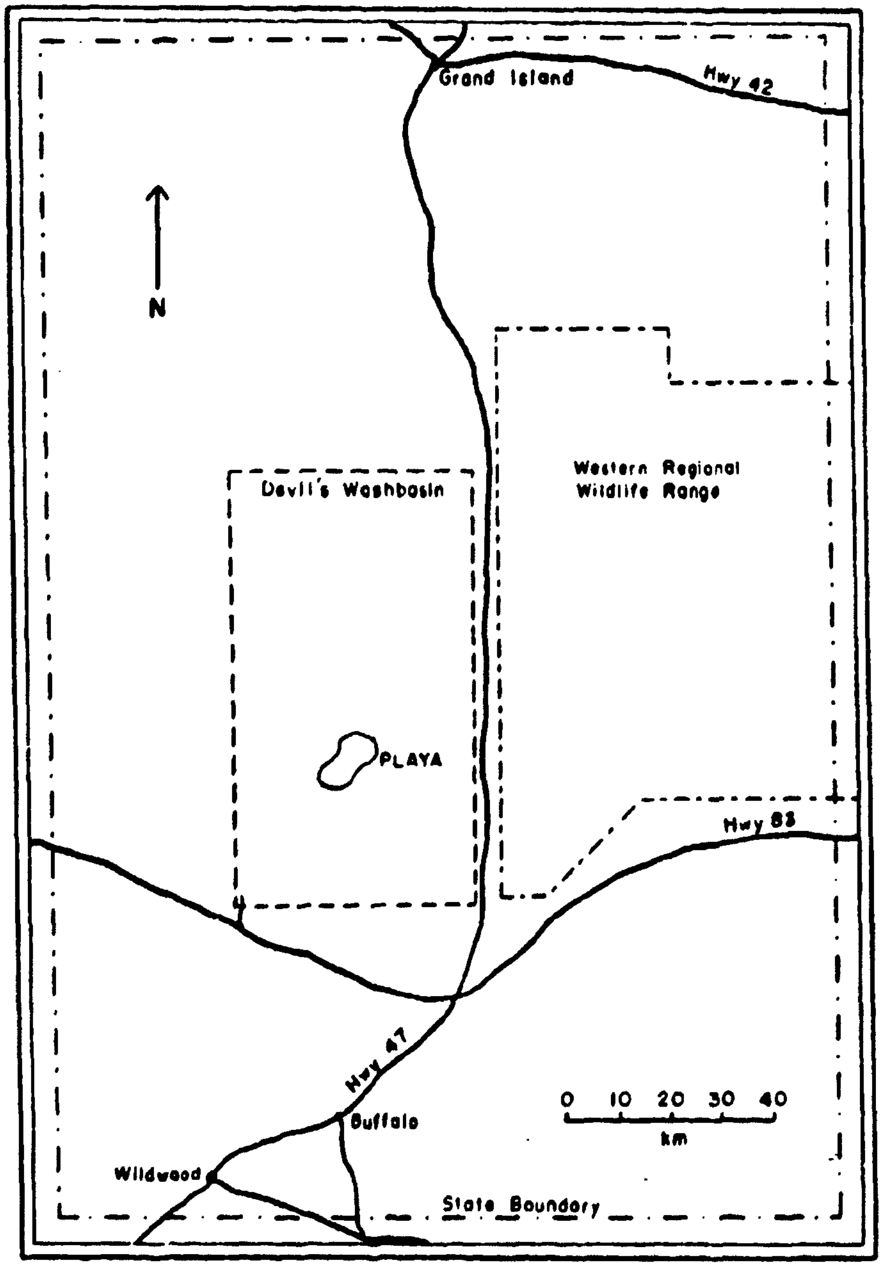

Figure 2. Location map, Devil's Washbasin.

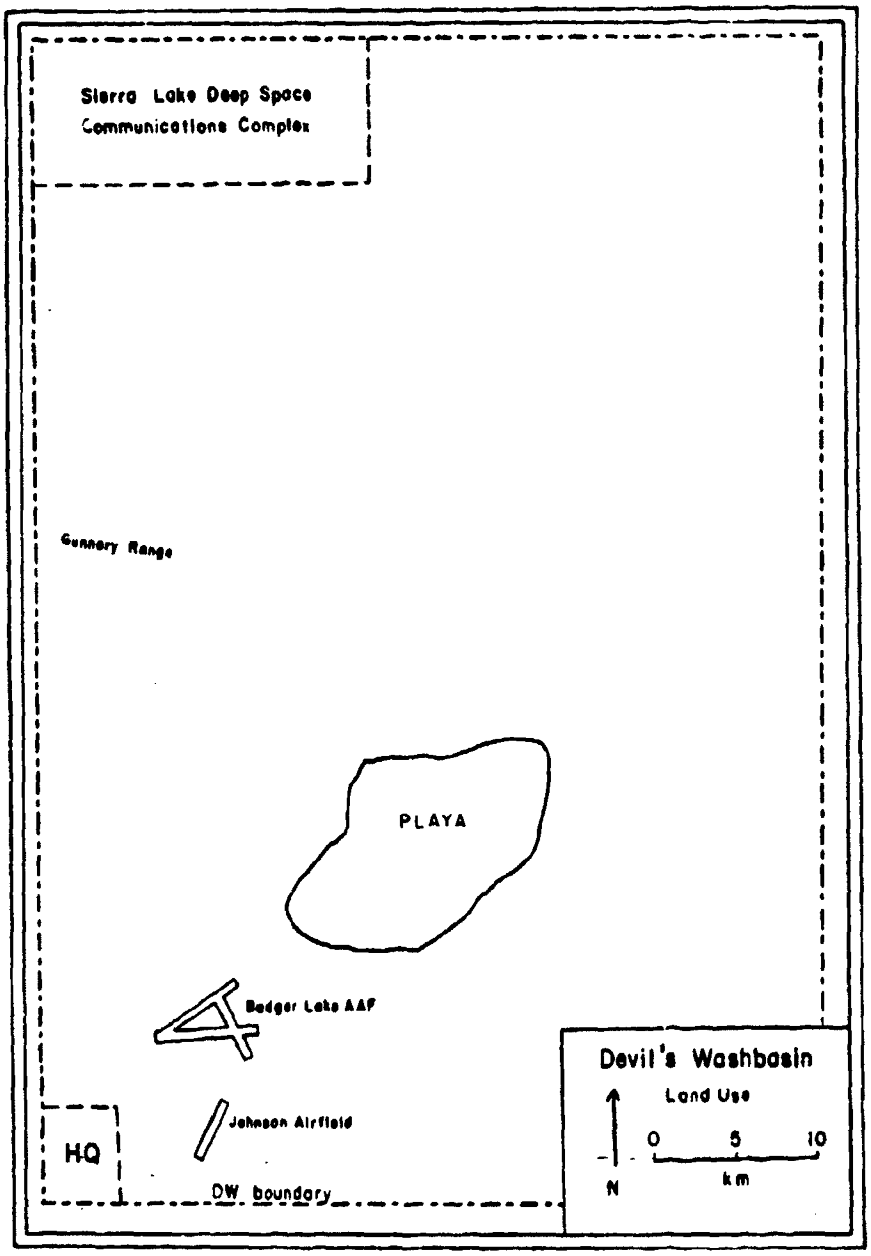

Figure 3. Land use operations at Devil's Washbasin.

The Environmental Protection Agency is required by the CAA to review primary and secondary standards for the five major criteria pollutants: sulphur dioxide (SO_2), nitrogen dioxide (NO_2), total suspended particulates (TSP), carbon monoxide (CO), and ozone (O_3). In addition, seven substances have been listed as hazardous under Section 112 of the CAA: asbestos, mercury, beryllium, vinyl chloride, benzene, radionuclides, and arsenic. In July 1979, states were required to bring air quality up to national standards in areas where continued violations of federal air quality standards for the major and hazardous pollutants occurred.

The second step is to identify the smokes emitted and the reaction products caused by the ignition of those smokes.

White phosphorus will react spontaneously with oxygen in the air. This oxidation of the phosphorus results in its burning and, therefore, the production of smoke. When the phosphorus oxides, phosphoric pentoxide and phosphorous trioxide, which are the combustion products of the initial reaction, come into contact with moisture in the air, they are transformed into phosphoric acid and phosphorous acid. In the smoke cloud, there will also be a certain amount of unreacted phosphorus and small amounts of other chemicals and compounds.

Third, determine the existing ambient air quality in the test area.

The background air quality at Devil's Washbasin is good. There is generally a good level of atmospheric dilution of air contaminants due to the prevailing westerly winds in the summer and fall and the Pacific storm track in the winter and spring. The atmosphere at Devil's Washbasin is generally stable with occasional desert thunderstorms. Air stagnation in the area is rare and there has never been an air pollution alert at Devil's Washbasin. Pollutants emitted from various sources at Devil's Washbasin are quickly dispersed into the upper atmosphere. This results in low ground-level pollutant concentrations.

Mixing height for the area is typical of desert regions. In the daytime, it is the top of the thermal convection layer, while at night it can be very low and capped by an inversion.

The emissions from the Grand Island power station, located 90 km north of Devil's Washbasin, have an effect on the air quality of the region. It is the only source of pollutant emissions for the entire area, however.

Fourth, analyze and summarize the basic meteorological data for the area.

There are two major air-movement patterns that affect the weather at Devil's Washbasin. Prevailing westerly winds from the Pacific exert their influence from spring through fall. Then, as the Pacific high-pressure ridge dissipates in the fall, the warm, moist airmass from the southeastern Pacific exerts its influence.

There is an average of 10 cm of precipitation each year on the Devil's Washbasin floor with higher amounts in the mountains and ridges. Humidity is typical for a desert area and is generally low, with an average of 10 to 25%.

Average daily temperatures are lowest in January (-4°C) and highest in August (30°C).

Westerly winds predominate in the summer and southerly winds predominate in the winter. Average hourly wind speeds may reach 9 m/s on spring afternoons. Wind gusts will occur throughout the year but generally occur with summer thunderstorms. Wind speeds in summer at Devil's Washbasin are generally light and range from 1 to 3 m/s.

Fifth, determine the air pollution dispersion potential for the area.

The factors most likely to affect the air pollution dispersion potential for Devil's Washbasin are the stability, wind speed and direction, and the terrain.

The most frequent air stability classification for this area is category D. It is quite common in the summer months, however, to have highly unstable air during summer thunderstorms. Winds are generally light at night and in the morning. Wind speed will increase rapidly during the afternoon and then drop off gradually through the late afternoon. It will decline more rapidly after nightfall (Fig. 4).

Because Devil's Washbasin is a desert basin with walls formed by mountains and ridges, the topography has an effect on the air pollution dispersion potential. The elevation extremes or differences will result in temperature differences and, therefore, there will be upslope winds during the day and downslope winds at night.

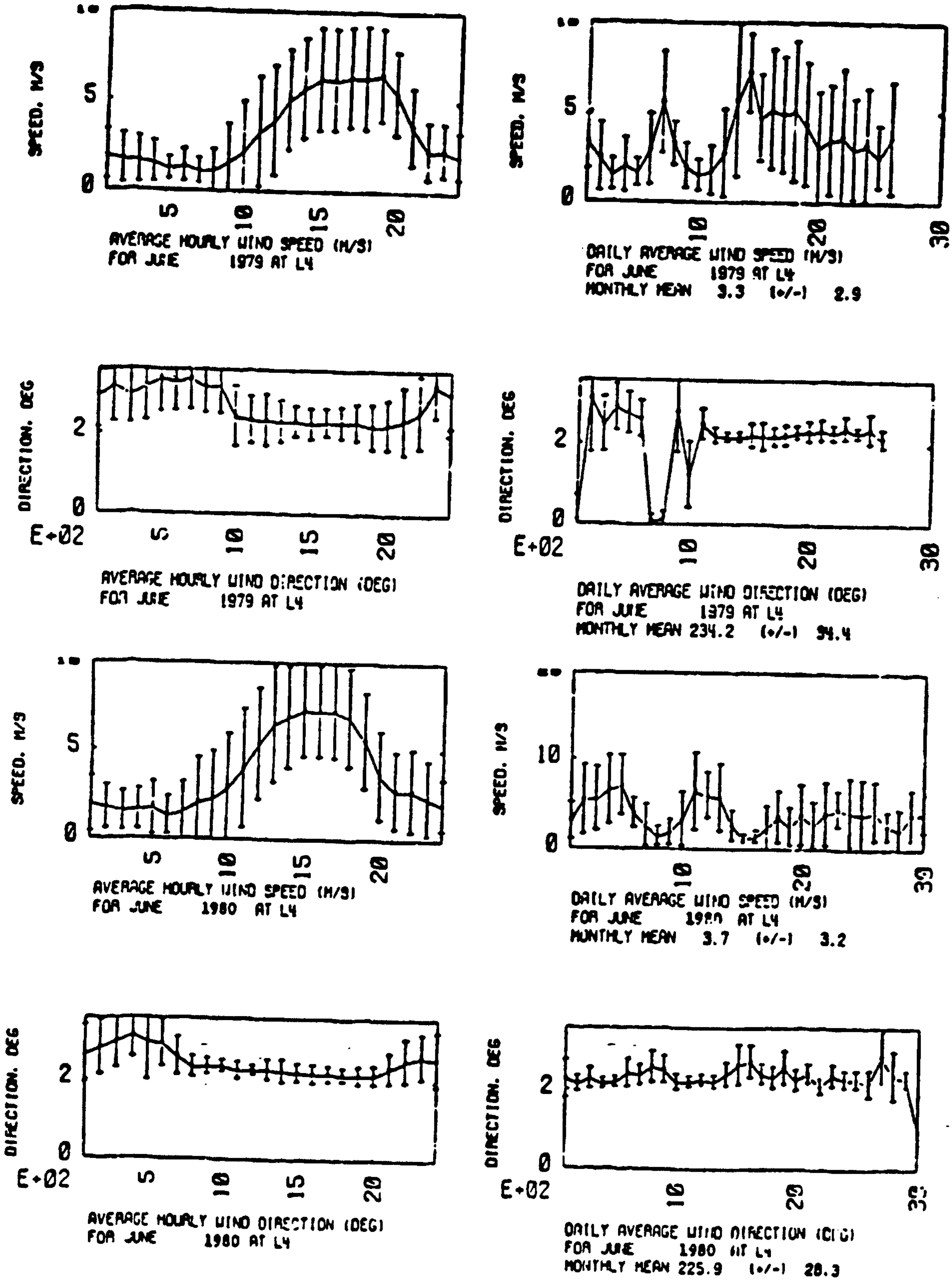

Figure 4. Average windspeed at Devil's Washbasin for June (1979-1980) from micrometeorological data, 2-m level, 62-m tower.

Sixth, obtain air quality and emissions standards for the area.

Devil's Washbasin is contained in Intrastate Air Quality Control Region 248 (AQCR-248), which is responsible for monitoring air quality in this state (Fig. 5). The city of Grand Island has its own Air Quality Control Region (AQCR-255).

The five major criteria pollutants are the standards with which the EPA is concerned. In AQCR-248, there have not been any violations of the CAA annual arithmetic means for SO_2 or NO_2 for a 5-year period from 1980 to 1985. TSP was higher than the arithmetic mean at several monitoring stations in Grand Island, but there were no violations reported in rural areas. Carbon monoxide concentrations, which are primarily the result of automoblies, are regulated in 8-hour and 1-hour averages but should not be of concern in the rural areas. Ozone, the product of photochemical oxidants, regulated by 1-hour averages, was in violation only 18 days of the 5-year period and will not be of concern to the smoke-test procedures. In the absence of an air quality standard or federal regulation for the ignition and release of smoke products, the state has adopted 2.4% of the Threshold Limit Value-Time Weighted Average (TLV-TWA) as a screening tool for locations in which the general public has access. The TLV-TWA is the government standard for an 8-hour occupational exposure in the workplace.

The seventh step is to compile an emission inventory.

The emission inventory for the Devil's Washbasin area is found in Table 1.

Finally, calculate the mesoscale/microscale impact. The computation of these effects is facilitated by a scaling principle in atmospheric dispersion:

(Concentration #1)x(Area #1) = (Concentration #2)x(Area #2).

We recommend that the area of impact be estimated that will have an increase in average total suspended particulates (TSP) equal to the national ambient air quality standard (NAAQS). We use a MAC-factor for Concentration #1, the minimum impact area (A) for Area #1, the NAAQS for TSP as Concentration #2, and solve for Area #2 as the mesoscale area of significant effect. The MAC-factor is the maximum airborne concentration (MAC) multiplied by the

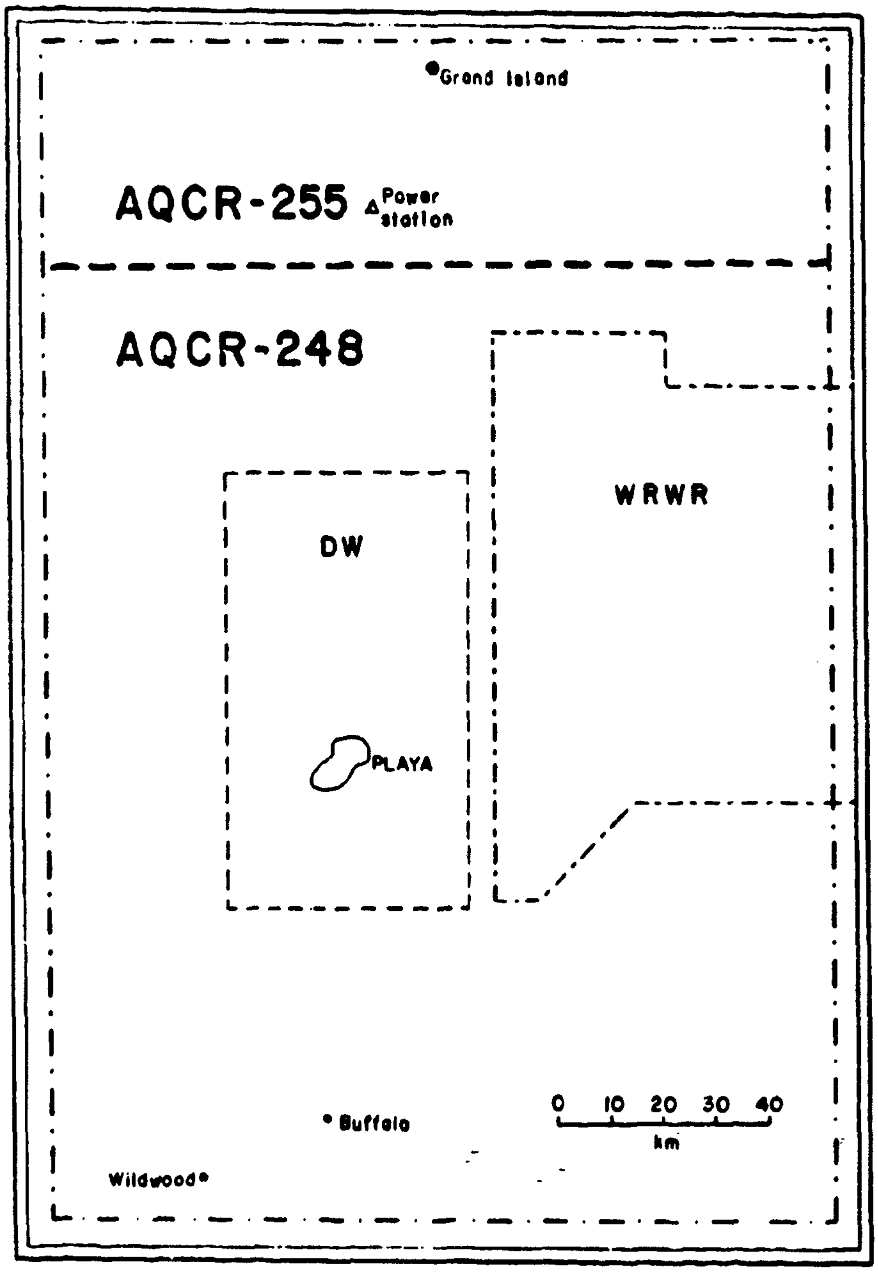

Figure 5. Air quality control regions of the state.

TABLE 1. EMISSIONS INVENTORY OF INTRASTATE AIR QUALITY CONTROL REGION 248.

Source	Rate or size	Activity	Estimated emissions (lbs/hour)				
			TSP	NO_x	CO	HC	SO_2
Boiler	500MM Btu/hr	Combustion	50	200	15	35	120
Rotary Kiln	500 tons/day	Heating	10	nil	nil	12	nil
Smelter	300MM Btu/hr (450 tons/day)	Smelting	30	120	10	55	100
Conveyors	1000 tons/day	Transport	200	nil	nil	nil	nil
Loaders	150 tons/day	Loading	180	nil	nil	nil	nil
Graders	4 Graders	Leveling	45	nil	nil	nil	nil
Trucks	4 150-Ton Trucks (each travel 10 mph)	Transport	35	nil	nil	nil	nil
Stockpiles	65,000 tons (2.5 acres)	Storage	11	nil	nil	nil	nil

number of hours of tests per week and divided by 168, the number of hours in a week. The NAAQS is 0.075 mg/m^3, annual geometric mean.

In deploying one M2 munition, the mesoscale/microscale effect area at Devil's Washbasin for 1 hour of testing per week is estimated as follows:

$$\frac{(3100 \text{ mg/m}^3)(516 \text{ m}^2)(1 \text{ hour/week})}{(0.075 \text{ mg/m}^3)(168 \text{ hours/week})} = 127{,}000 \text{ m}^2 .$$

This is the area that will have an average weekly increase in total suspended particulates (TSP) equal to the EPA standard of 0.075 mg/m^3 (annual geometric mean). The area 127,000 m^2 is 12.7 hectares or about 31 acres. The estimate is made by scaling up from the characteristics of M2 munition where the minimum impact area (A) is about 516 m^2 and the average airborne smoke concentration (MAC) is 3100 mg/m^3 over the area (A).

3. Water Quality

The environmental assessment evaluates the water in the area of the test by considering the quality of the water now and how it would be in the future both with the test and without it. An evaluation of the water should include a description of the existing water and its physical, chemical, and bacteriological characteristics.

3. Water Quality

a. The Existing Water. There are four types of water movement in Devil's Washbasin: rainfall, runoff from the surrounding mountains, groundwater, and Grand Island Creek. Direct rainfall averages 10 cm per year. Runoff from the mountains occurs only during heavy storms and is quite variable from year to year. Because the area is a closed basin with a hardpan near the surface, water reaching the playa accumulates in shallow ponds, which, depending on their size and the time of year, normally evaporate in a few hours to a few weeks.

Grand Island Creek drains the extreme northeast corner of the installation (Fig. 6). The source is located at an elevation of 4200 feet and

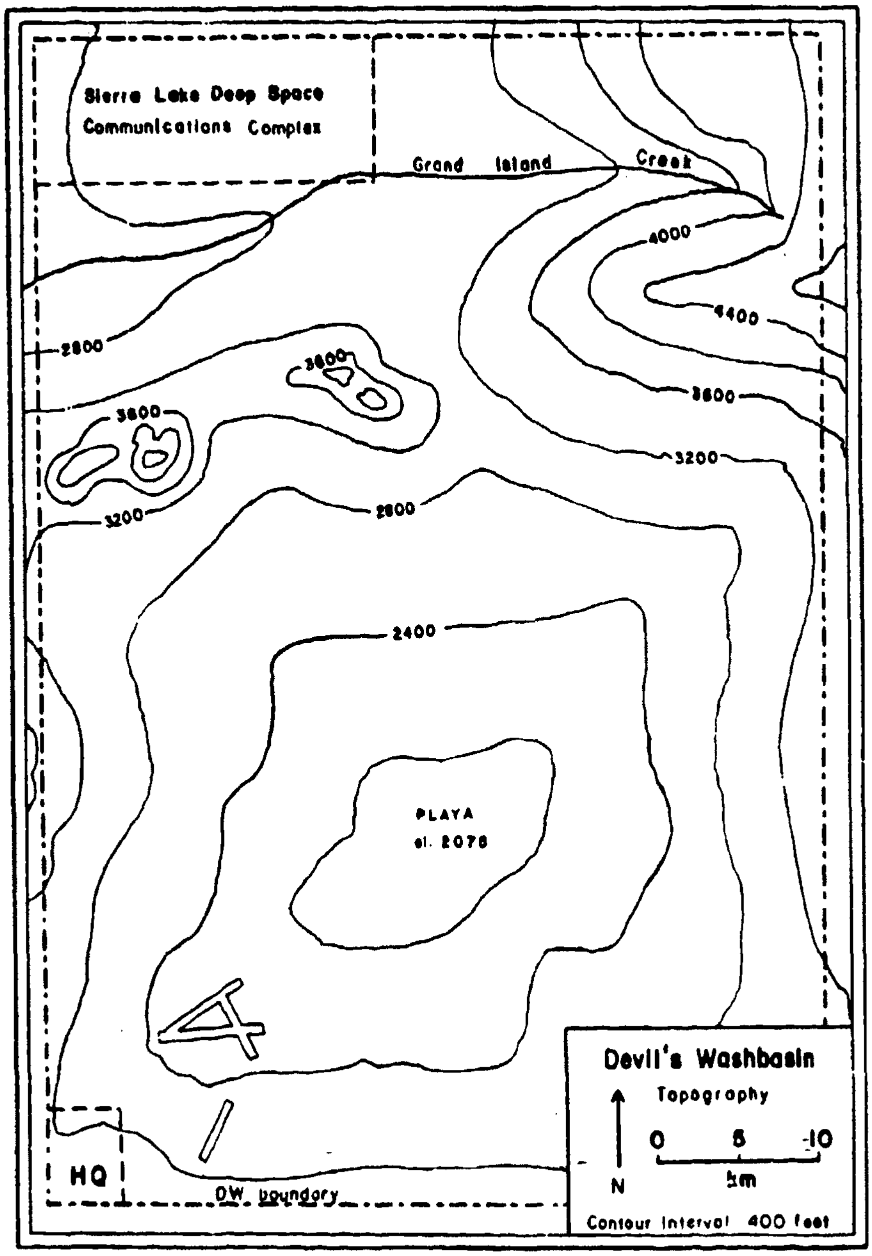

Figure 6. Topography of the Devil's Washbasin installation.

flows through the northern perimeter of the installation to the west during the summer months. It will continue to flow above 2,000 feet, but below that elevation, it is quite often dry. It averages 1 to 6 m in width and up to 3 m in depth in the winter. A biological evaluation of surface waters has determined the quality of water in Grand Island Creek to be generally good. The two natural drainages on the installation are usually dry throughout most of the year.

b. Physical Characteristics. Much of the water for the Devil's Washbasin installation is supplied by 12 wells located on the site. The physical characteristics of the well water vary slightly, but all are within the local and federal standards for drinking water. The well water is supplied by a 200-m-deep terrace alluvium, which is fed predominantly by underflow from the north. Recharge from precipitation is negligible.

Total output from the wells is approximately 842 acre-feet per year. The water table has dropped 15 feet in the thirty years since 1956.

The turbidity of the well water is measured at 45 Jackson Turbidity Units (JTU). The pH of the water is 7.5, and using the visual comparison method, the color of the water was given 37 color units. The odor of the water was measured using the taste threshold test and was given a rating of 3. The temperature range is 5°C to 22°C and the mineralization, measured as conductivity, was determined to be 163/mhos/cm.

The turbidity of Grand Island Creek was measured at 35 JTU and the pH is 7.4. It was given 25 color units on the visual comparison method and a taste rating of 2. The temperature range for Grand Island Creek is typical for a mountain stream and ranges from 4 to 10°C. Mineralization was measured at 242/mhos/cm.

c. Chemical Characteristics. The groundwater occurs principally in alluvial deposits underlying the valleys and the basin within the area (Fig. 7). The water from the terrace alluvium is a hard water, calcium carbonate type. Total dissolved solids average about 238 mg/L and total hardness averages about 150 mg/L. The iron concentration is negligible, but there is a generally high concentration of fluoride and occasional high levels of boron and nitrates.

The biological oxygen demand (BOD) for the wells is 201.8 mg/L with a standard deviation of 42 mg/L. The chemical oxygen demand (COD) is 214 mg O_2/L and, using the persulfate-ultraviolet oxidation method, the total

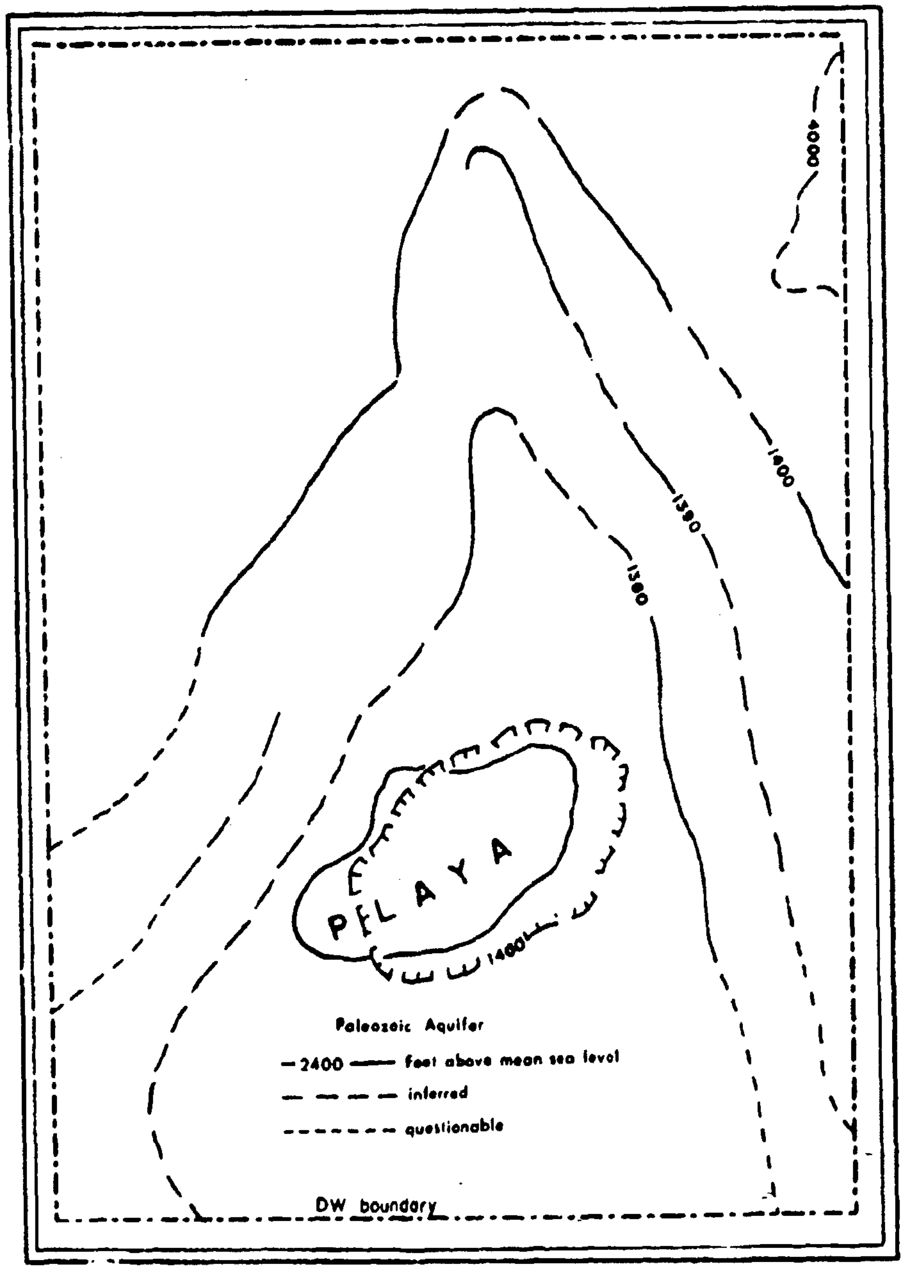

Figure 7. Groundwater map of the paleozoic aquifier underlying Devil's Washbasin.

organic carbon (TOC) was measured at 2.49 mg/L with a standard deviation of 0.02. Using the hydrometric method, salinity was measured at 2.4 g/kg.

Grand Island Creek has a BOD of 184.6 mg/L with a standard deviation of 27 mg/L. The COD is 208 mg O_2/L and the TOC is 0.336 mg/L with a standard deviation of 0.02. Using the hydrometric method, the salinity in the creek was measured at 1.2 g/kg.

d. Bacteriological Characteristics. Using the presence/absence of coliform test, the water in the wells and the water in Grand Island Creek were determined to be negative for coliform bacteria.

4. Geology, Topography, and Soils

The physical environment includes the geology, topography, and soils of the area, and a complete EA presents a description of these elements.

4. Geology, Topography, and Soils

a. Geology. The mountains of the Devil's Washbasin area are composed of Paleozoic sea-bed sediments consisting of lime tone, dolomite, quartzite, shale, and conglomerates (Figs. 8 and 9). During the Mesozoic period, they were upthrust and folded. Portions of the mountains were covered with Tertiary volcanic deposits, principally rhyolitic and quartz-latitic tufts. Quarternary deposits of eroded material from the surrounding mountains form the bajadas, which are sloping alluvial fans. Its sands, gravels, silts, and clays form a level flood plain. Because the sediments are relatively impervious to water, large shallow ponds form on the playa during rains, with the size of the ponds varying from year to year.

Two potentially active earthquake fault zones occur in Devil's Washbasin although no major earthquakes have been recorded since its settlement. The nearest occurred in the surrounding mountains in 1922. A number of "micro-earthquakes" of low magnitude have been recorded in the valley with the epicenter generally occurring in the southwestern area. This activity may have been the result of blasting during mining or munitions-disposal operations.

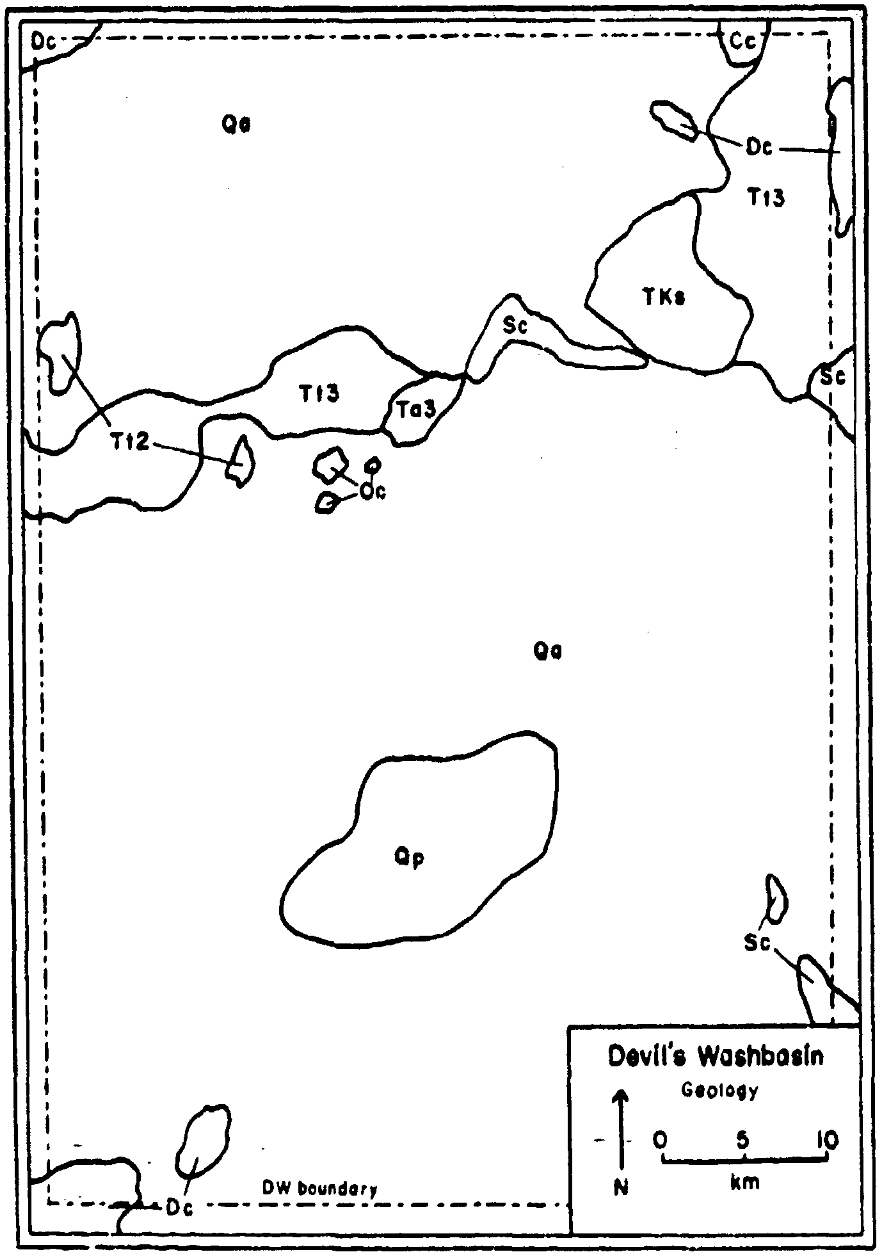

Figure 8. Geologic map of Devil's Washbasin; map index is located in Figure 9.

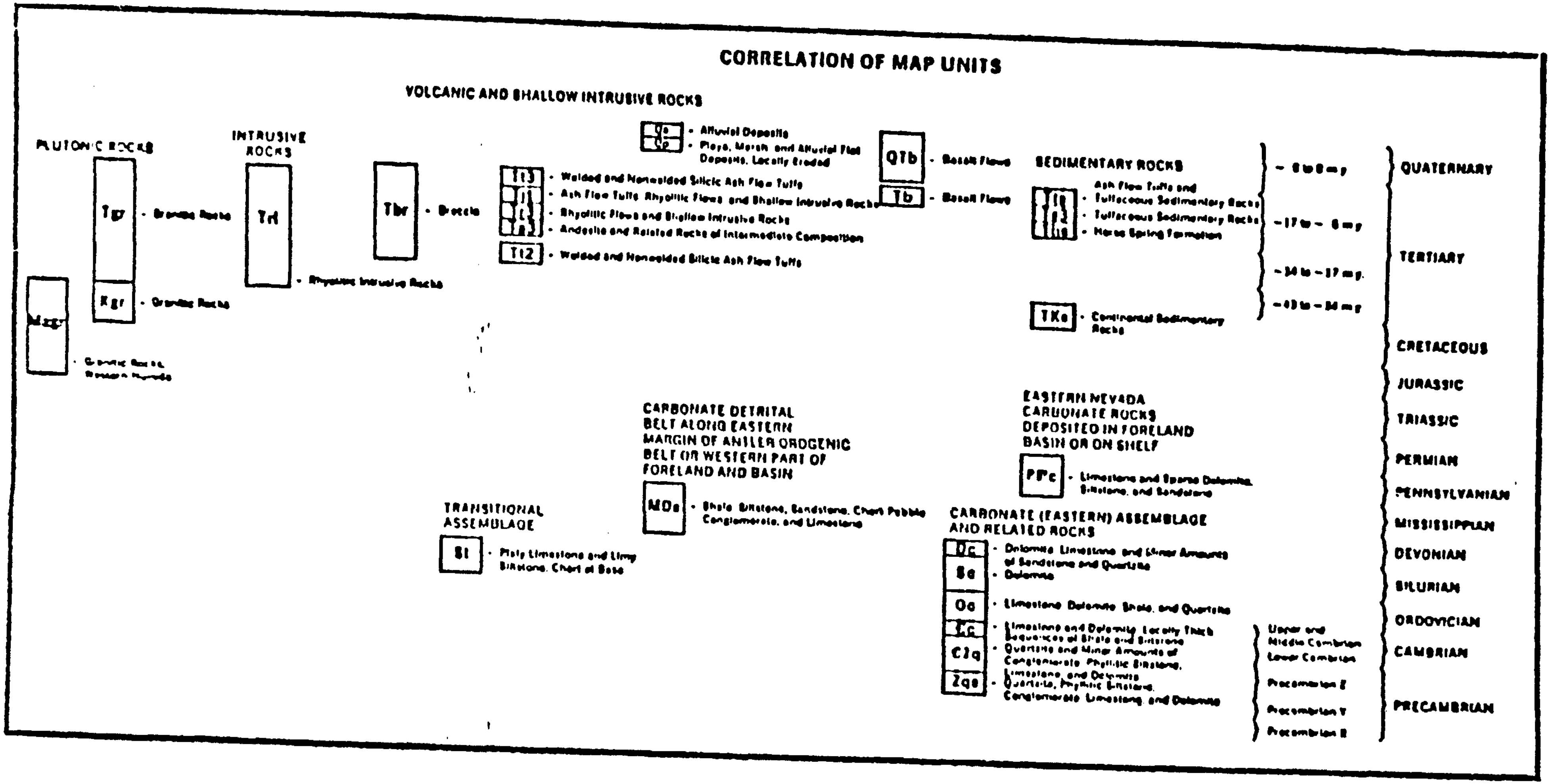

Figure 9. Map index to geologic map of Devil's Washbasin (Figure 8).

b. Topography. Devil's Washbasin is an oval-shaped desert basin with a dry lake bed (playa) in the center. The elevation of the desert floor is 2075 feet. Mountains and ridges form the walls of the basin, and bajadas merge with the valley floor.

The mountains surrounding the Devil's Washbasin area have been mined for many years. The region has a wide variety of mineral resources, with the major minerals extracted being copper, dolomite, gold, gravel, lead, limestone, mercury, salt, sand, silver, and zinc.

c. Soils. The soils of the Devil's Washbasin area are typical desert soils, formed slowly under conditions of low moisture and high temperature. They are of the major group Pedocal. The soils have formed over a mixture of limestone and alluvium, and tend to be quite alkaline (pH 8 to 9). Where there is a high proportion of limestone, such as in the southern portion of Devil's Washbasin, the soils have high carbonate levels. Calcification occurs where evaporation normally exceeds precipitation and rainfall is insufficient to leach the soils. This leads to the development of a restrictive hardpan, usually within 70 cm of the surface. The coarsest soils are found near the mountains and bajadas. Finer textured soils are found in the valleys and flats. They have little moisture retention capacity and contain almost no organic material. Because the area is a closed basin, the lower elevation soils accumulate salts. The soils in and around Devil's Washbasin have a very high concentration of alkalai salts.

A soil analysis of the Pedocal soil group at Devil's Washbasin is presented in Table 2.

5. Meteorology

In assessing the physical environment, it will be necessary to analyze the climatological conditions in the area of the test. Depending on both short-term meteorological conditions and long-term climatology, it may be necessary to alter the proposed action to assure that the smoke plume will be effectively dispersed. An adequate meteorological assessment will include a climatological narrative, and discussion of temperature, humidity, precipitation, wind and dispersion potential, and local airflow patterns.

TABLE 2. ANALYSIS OF THE PEDOCAL SOIL GROUP AT DEVIL'S WASHBASIN.

pH	8.43
Organic Carbon (C)	0.74%
Sulphur (S)	0.025%
Nitrogen (N)	0.095%
Total Phosphorus (P)	716 μg/g
Phosphate (PO_4-P)	6.7%
Fine and Clay	33.4%
Carbonate (CO_3+HCO_3)	4.65%
Total Available Nitrogen (expressed as ammonia, NH_4-N)	99 μg/g

5. Meteorology

a. Climatological Narrative. Two major air-movement patterns affect the weather at Devil's Washbasin. Pacific air flowing westerly over the western mountain range exerts its influence from late spring through fall. Then, in late fall when the Pacific high-pressure ridge dissipates, the Pacific winter-storm track takes over.

b. Temperature, Humidity, and Precipitation. The average daily temperatures are lowest in January (-4°C) and highest in August (30°C). Large daily fluctuations in temperature are common, especially on the valley floor. January temperatures at Devil's Washbasin can vary from -7°C to 14°C during a 24-hour period, while August temperatures show a daily range from 18°C to 36°C. At higher elevations, the daily variation in temperature is not as pronounced. The winter temperatures are lower, and the daily range is only a few degrees. In the summer, the daily range may be more than 10°C.

The relative humidity at Devil's Washbasin is typical for a desert area and ranges from 10 to 25%.

Although precipitation is highly variable, two peaks of annual rainfall can be detected, the larger in winter and the smaller in late summer. The July and August summer rainfall often comes in intense thunderstorms that can cause local flashfloods. The average annual precipitation is largely a function of altitude within this region, with higher elevations receiving more than the lower elevations. The valley floor averages about 10 cm of precipitation per year. The higher mesas and mountains average 30 cm, with some precipitation falling as snow. Standing water on the valley floor is common during the winter, and may have a frozen surface.

c. Wind and Dispersion Potential. Three main influences on the directional wind patterns occur at Devil's Washbasin: large-scale movement of major air-pressure systems, intermediate-scale air movements due to regional topographic features, and localized effects due to terrain. As with rainfall, the Pacific airmass influences the winds from spring through fall. Northerly winds predominate in winter. Because there is a general topographic trend toward higher elevations in the northern portion of the area, the differential heating of the surface results in southerly (upslope) winds during the day and northerly (downslope) winds at night. This

intermediate-scale effect is most pronounced during the summer and frequently overrides the large-scale pattern. In turn, this regional pattern is strongly influenced by local terrain effects such as the orientation of valleys and ridges.

The annual pattern of wind speeds at Devil's Washbasin is marked by strong winds in the spring and mild winds in the fall. The daily cycle shows little wind at night, increasing wind speeds from morning to afternoon, and declining wind speed in the evening. Average hourly wind speeds may reach 9 m/s on spring afternoons. Wind gusts are often much stronger than hourly averages. Gusts occur throughout the year, but are often recorded in conjunction with late summer thunderstorms. Gusts of 28 m/s are noted every few years and wind speeds have exceeded 45 m/s in the past.

d. Local Airflow Patterns. Local topographic features modify the broad wind pattern. The basin itself is essentially flat and is devoid of any relief that would give rise to eddies or local convection currents. However, wind-flow patterns related to two nearby drainages exert considerable influence. The larger of the two lies to the north. The smaller adjoins Devil's Washbasin to the east. Because little afternoon sun strikes the larger drainage, it begins to cool after sunset. During the night, cool air flows southerly out of it and across the valley. In conjunction with the summer prevailing westerlies, this results in northwest-to-west winds throughout the night. After sunrise, the larger drainage warms faster than the smaller, and an easterly flow out of the smaller drainage dominates for a few hours. By midmorning, the prevailing winds are out of the south (upslope flow), and by midday they are from the southwest (combined with the prevailing westerlies). There is a consistently southwesterly wind throughout the afternoon (Fig. 10 shows a typical summertime pattern). As the sun sets, cool air flowing downslope out of the larger drainage causes the wind to shift to a northwesterly direction. This directional pattern is most pronounced and consistent during the summer months.

Wind speeds in the summer at Devil's Washbasin are generally light and average 1 to 3 m/s from midnight until almost noon. As noon approaches, average hourly wind speeds increase rapidly to about 7 m/s by mid-afternoon (Fig. 4). Wind speeds drop off gradually through the late afternoon and then decline more rapidly after nightfall. Average daily wind speeds are usually below 3 m/s.

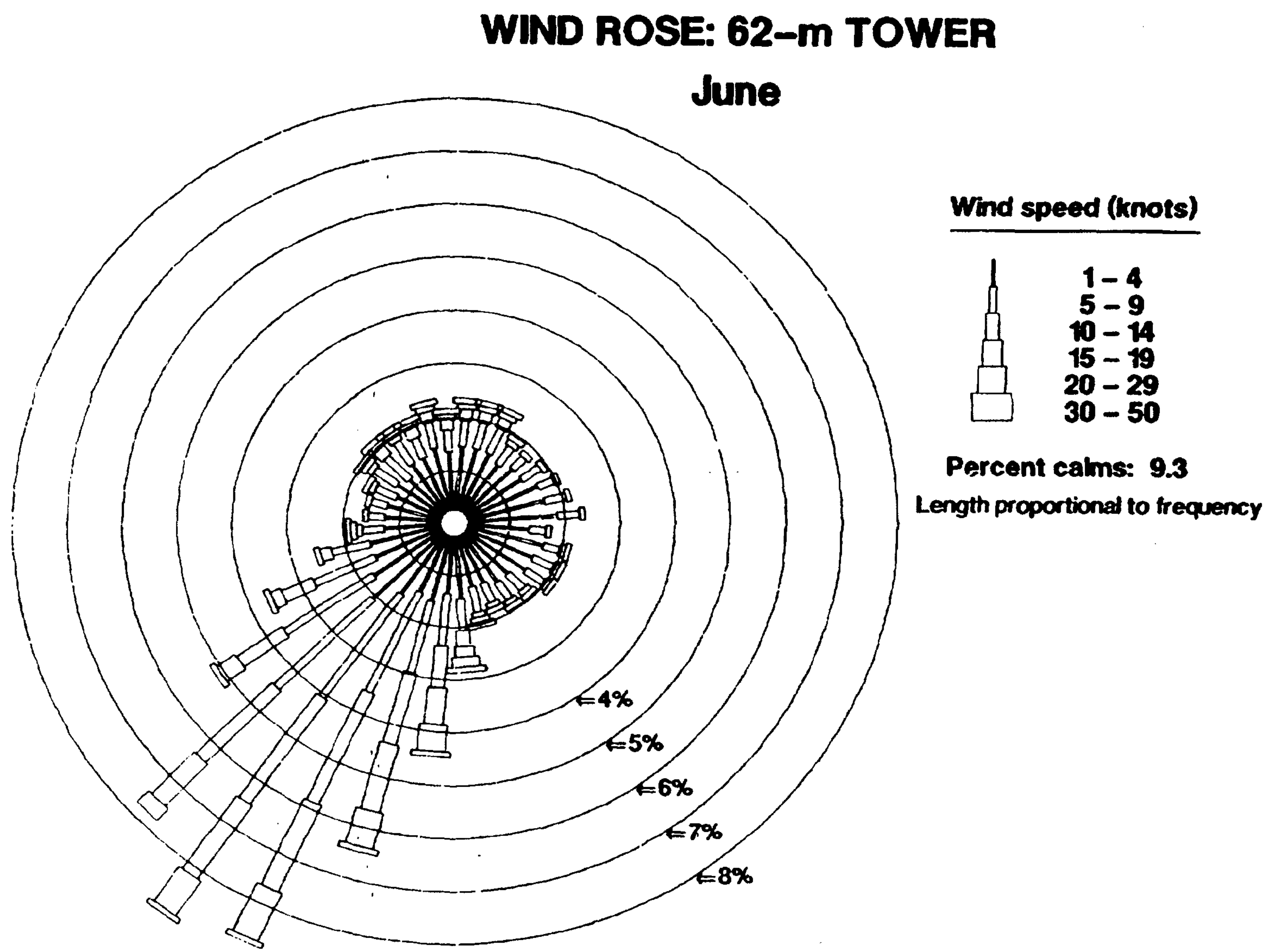

Figure 10. A typical summertime-pattern wind rose for winds measured at a 10-m tower at DW4, just east of the playa; north is at the top.

B. BIOLOGICAL AND ECOLOGICAL FACTORS

1. Aquatic Environment

An aquatic habitat will be determined by the water and the land around it. Testing does not have to occur near a body of water for it to have an impact on an aquatic system. Because Devil's Washbasin is in a desert area, its aquatic environment is minimal. An assessment of the aquatic environment of other non-desert areas would be more complex and have greater detail. An analysis of the aquatic environment includes descriptions of both the niches and the habitats of the area.

B. BIOLOGICAL AND ECOLOGICAL FACTORS

1. Aquatic Environment

The aquatic environment at Devil's Washbasin includes Grand Island Creek and the mud and ponds created by precipitation.

Grand Island Creek supports a variety of small aquatic plants and animals as well as a large variety of terrestrial wildlife. In the headwaters and upstream area of the creek, the number of animal species and the size of each species population is smaller than is found downstream. This is due primarily to the size and types of habitats that are available. In the upstream area, the flow is smaller and precipitation accounts for a higher percentage of the total flow than downstream. During periods of flash flooding, the creek is scoured, and this results in a loss of available nutrients and habitats. As a result of this seasonal flooding, the resistant species have multiplied while the less resistant species have declined in number.

Downstream, the volume of water increases and nutrients become more available. This results in an increase in the number of species and individual organisms. The environment downstream is more stable as well, and is not subjected to the extreme variations in environmental quality to which the upstream environment is subjected.

The upstream area, located above 4000 feet, flows intermittently and, as a result, little aquatic life is supported there. However, volunteer

cottonwoods (Populus *sargentii*), tamarisk (*Tamarisk gallica*), and some phraetophytes use the higher water table and soil moisture found near the streambeds. Excessive runoff during thunderstorms makes the streambeds difficult to populate.

As the creek flows downstream, the number of plant and animal species and their habitats increase. In the area below 4200 feet where the creek flows year-round, about the average number of aquatic biota that would be expected to inhabit a desert mountain stream are present. The vegetation is dominated by volunteer cottonwoods (Populus *sargentii*), cattails (*Typha latifolia*), and bullrushes (*Scirpus americanus*). A substantial crop of elodea grows along the banks of the creek. Black bullhead (*Ictalurus melas*) and rainbow trout (*Salmo gairdneri*) have been observed in the areas below 3000 feet. Large numbers of tiger salamanders (*Ambystoma tigrinium*) and leopard frogs (*Rana pipens*) have been collected from the areas below 2000 feet. In addition, a substantial amount of aquatic invertebrates such as water fleas (*Daphnia*), segmented worms (*Anneliola*), and midges (*Tendies*) are supported by the environment. Biological surveys conducted by the US Fish and Wildlife Service have determined that the creek also supports a small number of fathead minnows (*Pimephales promelas*).

The seasonal flooding, together with precipitation, can sometimes result in standing water and muddy flats on the valley floor. When this water remains for more than a few days, it will support caddis flies (*Tendipedidae*), stone flies (*Alloperta*), and anthomids (*Limnophara*).

Several studies have shown that there are no endangered or rare species of aquatic organisms at Devil's Washbasin and there are no habitats that would be likely to support them.

A complete list of aquatic organisms found at the site may be found in Table 3.

2. The Terrestrial Environment - Vegetation

In assessing the terrestrial environment, it is important to remember that if the smoke testing will significantly alter the habitat of the area of the test, then it can potentially alter the type of organisms found there. Since all of the elements in the environment are interdependent, this can have a significant impact on the ecology of the entire area.

TABLE 3. AQUATIC BIOTA AT DEVIL'S WASHBASIN.*

Biological name	Common name	Occurrence
FLORA		
Populus sargentii	Cottonwood	Common
Tamarisk gallica	Tamarisk	Common
Typha latifolia	Cattail	Common
Scirpus americanus	Bullrush	Common
Amaranthus hybridus	Smooth Pigweed	Common
FAUNA		
Ictalurus melas	Black Bullhead	Common
Salmo gairdneri	Rainbow Trout	Common
Pimephales promelas	Fathead Minnow	Common
Abystoma tigridium	Tiger Salamander	Common
Rana pipens	Leopard Frog	Common
Daphnia	Water Flea	Common
Anneliola	Segmented Worm	Common
Tendies	Midge	Common
Tendipedidae	Caddis Fly	Common
Alloperta	Stone Fly	Common
Limnophara	Anthomid	Common

* Patton et al., 1986.

It is often helpful to assess the vegetation and the wildlife of the area separately, as it has been done here.

A number of steps are necessary to adequately assess the terrestrial environment. First, the constraints of the habitat in the area of the proposed tests should be identified. What is it about the physical environment of this particular habitat that makes it unique? The geography and time variations of these habitat constraints as related to the populations in the area should be determined.

2. The Terrestrial Environment - Vegetation

The distribution of vegetation at Devil's Washbasin is complex and is dependent upon topography and exposure. The site is a transition zone between a high-elevation desert and a low-elevation desert and, as a result, plants from both desert regions are found here. Vegetation associations from the high desert are found in the cooler, high-elevation areas above 4000 feet, while plants characteristic of the low desert are found at the lower elevations. Elevations in between these two areas often support a mixture of vegetation types. Extreme variations in the local climate and topography, such as the environment of Grand Island Creek, can produce many exceptions to the general pattern.

Second, a vegetation analysis or a reconnaissance evaluation should be conducted.

a. Plant Associations. The dominant shrub species at Devil's Washbasin form six major vegetation associations:

- *Larrea tridentata* **(creosote bush).**
- *Atriplex sp.* **(salt bush).**
- *Lycium pallidum* **(wolfberry).**
- *Lycium shockleyi* **(wolfberry).**
- *Ephedra-Atriplex* **(Mormon tea, salt bush).**
- *Coleogyne ramosissima* **(blackbrush).**

The playa itself does not support any plant life, but these plant associations are found around it (Fig. 11). The shrub species found in each association are listed in Table 4. In addition to these six major associations,

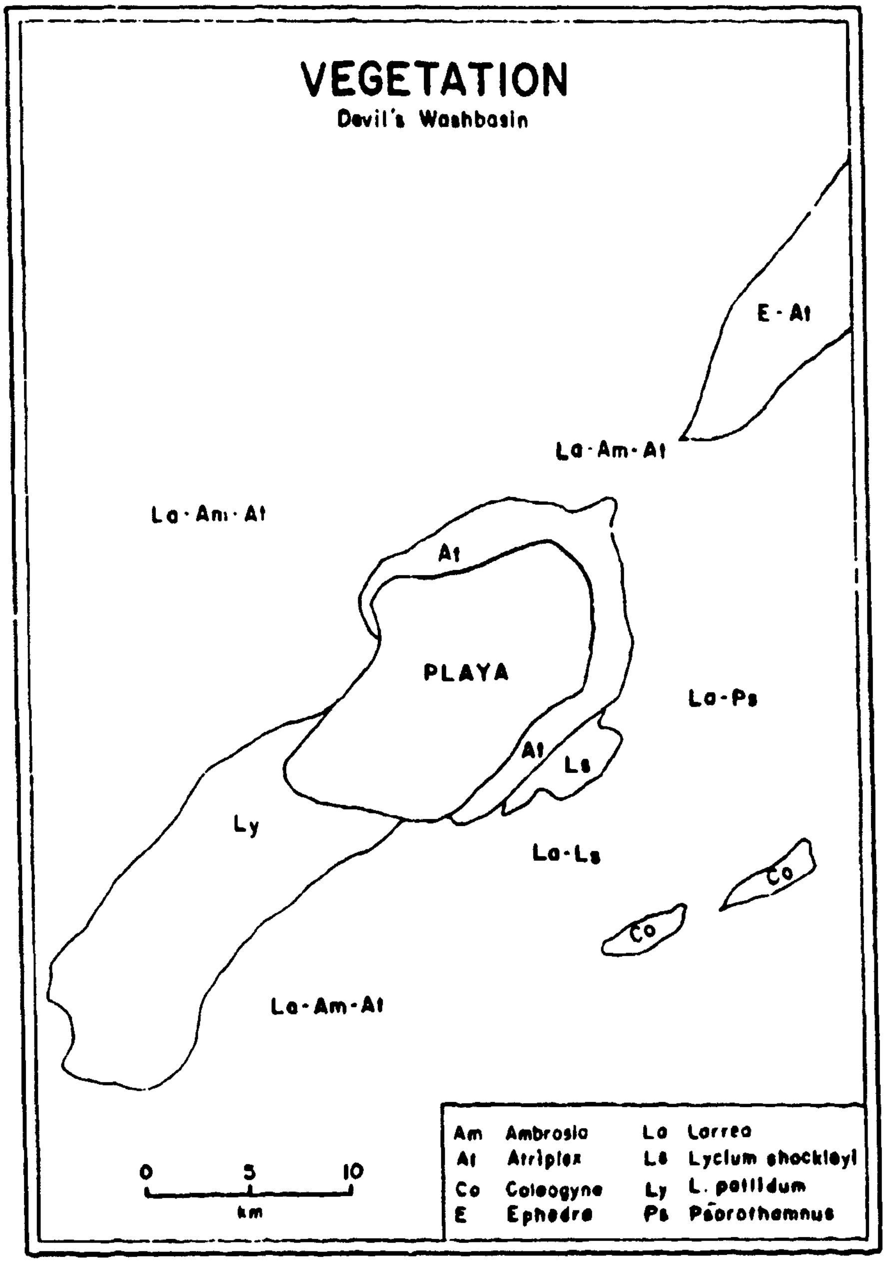

Figure 11. Vegetation associations of Devil's Washbasin.

TABLE 4. SHRUB COMPONENTS OF THE SIX VEGETATION ASSOCIATIONS FOUND IN DEVIL'S WASHBASIN; ALL ARE COMMON SPECIES.*

Acamptopappus shockleyi
Ambrosia dumosa
Artemisia spinecens
Atriplex canescens
Atriplex confertifolia
Ceratoides lanata
Coleogyne ramosissima
Encelia virginensis
Ephedra funereus
Ephedra nevadensis
Grayia spinosa
Hymenoclea salsola
Krameria parvifolia
Larrea tridentata
Lycium andersonii
Lycium pallidum
Lycium shockleyi
Opuntia spp.
Psorothamnus fremontii
Stanleya pinnata
Yucca baccata
Yucca brevifolia

* Patton et al., 1986.

riparian vegetation is associated with Grand Island Creek. There have been a number of investigations of the plant associations at Devil's Washbasin (Allred et al., 1963; O'Farrell and Emery, 1976; O'Farrell et al., 1982).

The largest and most extensive desert-shrub association at Devil's Washbasin is the *Larrea tridentata* association. It is a typical low-desert plant and is found in many forms in this region. It is distributed from just above the playa up onto the surrounding bajadas. Three subtypes are also found. They are the *Larrea-Lycium shockleyi* subtype found on the south bajadas, the *Larrea-Psorothamnus* subtype found on the eastern bajadas, and the *Larrea-Ambrosia-Atriplex* subtype found to the northwest, northeast, and south of the playa. The *Larrea* and *Ambrosia* species are low-desert plants and the Atriplex is a high-desert plant. Almost 15% of the perennial shrub cover in the region is made up of the *Larrea* association.

Cold air drains into the basin at night and because of this, a high-desert plant association, *Atriplex*, is found around the edge of the playa below the *Larrea* association. Ordinarily, this association would be expected to occur at much higher elevations. The two dominant species are *Atriplex confertifolia* and *A. canescens*. About 6% of the perennial shrub cover is of the *Atriplex* association.

The *Lycium pallidum* association is found southwest of the playa. This association is transitional between the high- and low-desert types. The occurrence of this association at low elevations is probably due to the cold air drainage but may be due to the soil type as well. This shrub cover amounts to about 19%.

On the southern side of Devil's Washbasin is a very small area of the *Lycium shockleyi* association. Since *L. shockleyi* is a transitional association, it is found between the low-desert association (*Larrea*) and the high-desert association (*Atriplex*). It is also found scattered between the plants of the *Atriplex* association. These plants make up about 17% of the shrub cover.

The *Ephedra-Atriplex* association is found northeast of the playa and above the *Larrea* association. The area where it is found is a small wedge-shaped patch that gradually widens as it extends northeast. It is a typical high-desert association. The dominant shrubs in this association are *Ephedra nevadensis* and *Atriplex confertifolia*. *Krameria parvifolia* and

Ambrosia dumosa, two species found in the adjacent Larrea association, are codominants in the *Ephedra-Atriplex* association. Average cover for this association is about 18%.

Two narrow bands of fairly dense *Coleogyne ramosissima* run through the *Larrea* association southeast of the playa. It is found at elevations of about 800 m at Devil's Washbasin and is typical of the transitional zone. The stands of *Coleogyne ramosissima* have an average cover of about 42%.

Many of the more than 700 plant species collected at Devil's Washbasin are herbaceous annual plants that appear in the winter and spring after significant rains. Rainfall between September and late December is a determining factor in the abundance and productivity of these annuals. The seeds of many cannot germinate with less than 2.5 cm of rain. With higher amounts of precipitation, there is greater seed germination and seedling survival. The species composition varies from year to year and there is often a solid carpet of annuals covering the spaces between the shrubs (O'Farrell and Emery, 1976; Beatley, 1976; Allred et al., 1963; Romney et al., 1973).

Human activity at Devil's Washbasin has resulted in the introduction of various non-native plants. They are predominant in areas such as roadsides, and generally consist of five types: two grasses (*Bromus rubens* and *B. tectorum*), two Russian thistles or tumbleweeds (*Salsola iberica* and *S. paulsennl*) and a forb (*Halogeton glomeratus*). These plants can delay the natural revegetation of native plants by invading areas where the soil has been disturbed or native shrubs have been removed (Allred et al., 1963; O'Farrell and Emery, 1976).

There has not been a detailed botanical study of Grand Island Creek, but the vegetation includes cattails, reeds, willows, and sedges.

Third, the growing season should be determined.

b. Desert Vegetation and Seasonal Photosynthetic Production. Most desert plants carry out their photosynthesis and growth during favorable spring conditions of high soil moisture and moderate temperatures. Most will go dormant during the stressful summer months, but a few have adapted to the summer conditions of low soil moisture and high temperatures. They will carry on photosynthesis and growth in a reduced capacity.

Kleinkopf et al. (1980) researched the transpirational and photosynthetic strategies of desert species at Devil's Washbasin. The study showed that *Atriplex canescens* was highly competitive in growth and production during times of high soil moisture, but the net photosynthetic production decreased to zero during the summer conditions of higher temperatures and lower soil moisture. On the other hand, the study showed that *Larrea tridentata* maintained a positive net photosynthetic production during summer conditions.

Another study (Bamberg et al., 1975) investigated how several desert shrubs alter photosynthetic production in response to the environmental stresses of summer conditions:

- *Larrea tridentata*, an evergreen shrub with low photosynthetic rates, has the ability to depress transpirational loss during periods of moisture and temperature stress and to conduct photosynthesis during any favorable period. CO_2 uptake is restricted to the morning hours in summer.
- *Krameria parvifolia* is green in summer and has low photosynthetic rates during periods of summer stress. Its rate of CO_2 uptake usually decreases to zero by the afternoon in summer. It is deciduous in winter.
- *Lycium sp.* is a drought deciduous plant with leaf abscission in summer. It has a slight ability to withstand high temperatures and low moisture stress.

Fourth, the impact that testing will have on the habitat constraints and natural succession should be analyzed.

c. Range-Fire Potential. The ignition of white phosphorus munitions always carries with it the possibility of burned vegetation. At the Devil's Washbasin site, with conditions of low relative humidity, low precipitation, and high air temperatures, the range-fire potential will be great. The danger will increase, of course, in the summer months and will, at all times, be dependent upon the prevailing climatic conditions, fuel quantity, and the densities of adjacent vegetation associations. The perennial shrub cover of the *Atriplex* and *Larrea* associations and the density and quality of fuel at the site is low. Communication with the installation fire-fighting division should be maintained at all times.

d. Erosion. The burning of large areas of vegetation can often result in soil erosion in the area. This can be of critical importance in the Devil's

Washbasin area because of the shallow layer of topsoil and seasonal flash floods, which could easily wash away any soil that is not rooted.

e. Introduction of Nutrients. The reaction products of phosphorus smokes will be rapidly oxidized in the soil to become phosphates, which re plant nutrients. It is possible that these nutrients can have an effect on the natural succession in the area.

Fifth, whether any endangered or protected species will be affected by the tests should be determined.

f. Endangered or Protected Species. There are no plant species at the Devil's Washbasin site that are listed as threatened or endangered by the US Fish and Wildlife Service. There are, however, three species that have been found 15 km south of the test site that are candidates for inclusion under Category II of Endangered and Threatened Wildlife and Plants stated in the Federal Register (Fig. 12). These are *Astragalus beatleyae*, *Camissonia megalantha*, and *Phacelia funereus*. These three species are regarded as rare in this general area and are not found in the test area; they would be upwind during testing.

2. The Terrestrial Environment - Wildlife

To adequately assess the terrestrial environment, it will be necessary to evaluate a number of subjects. First, the constraints of the habitat in the area of the proposed test should be identified and the influence of geography and time variations of these habitat constraints on animal behavior of the populations in the area should be determined.

2. The Terrestrial Environment - Wildlife

Since Devil's Washbasin is a transitional zone between a high desert and a low desert, species of animals from both regions are found there. Most of the animals range widely throughout the area, but some are restricted to particular plant associations.

Hunting, fishing, and grazing are not allowed at Devil's Washbasin. The ammunition testing and Air Force bombing and gunnery tests have had only a

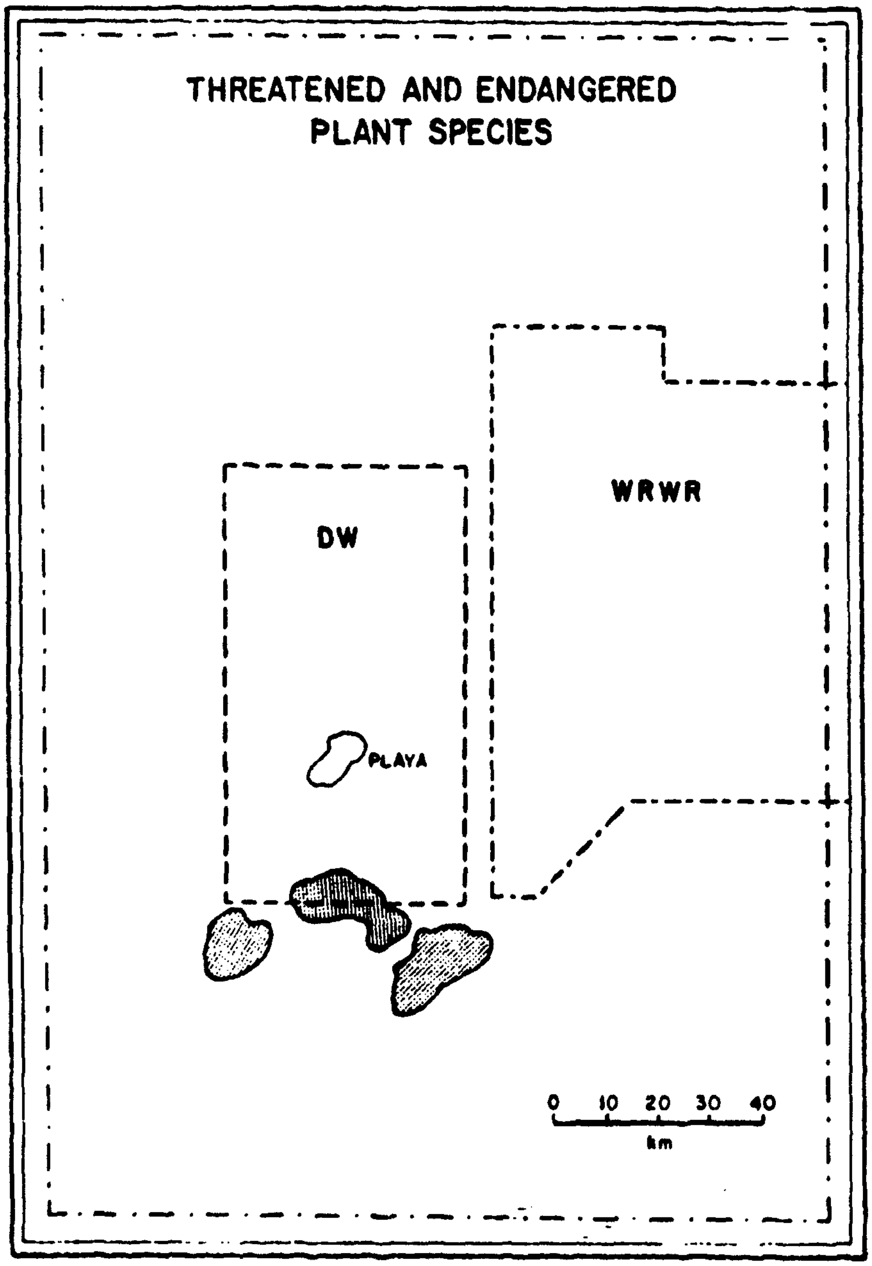

Figure 12. Location of plants listed in Category II, Threatened and Endangered Plants (Federal Register, Volume 48, Number 229, November 28, 1983). The species are *Astragalus beatleyae*, *Camissonia megalantha*, and *Phacelia funereus*.

slight effect on habitat modification or species interactions. There is generally little human impact on the natural population processes at Devil's Washbasin.

Second, an analysis of the animal populations of the area should be conducted.

a. Fish. Three fish species have been found in Grand Island Creek: black bullhead (*Ictalurus melas*), rainbow trout (*Salmo gairdneri*), and fathead minnows (*Pimephales promelas*). These species are common in the creek.

b. Amphibians. Both leopard frogs (*Rana pipens*) and tiger salamanders (*Ambystoma tigrinium*) have been found in Grand Island Creek; they are also common species in the area.

c. Reptiles. Because of the location of Devil's Washbasin between two desert areas, it is home to a particularly diverse reptile population.

The desert tortoise (*Gopherus agassizi*) is found at Devil's Washbasin; it is regarded as an occasional species. There have been several studies of desert tortoise ecology and its recent distribution (Tanner and Jorgensen, 1963; Collins, 1984). One study (Burge and Bradley, 1976) found the desert tortoise in a desert-shrub association at a nearby location dominated by *Larrea tridentata*, although shrub cover was much less than that at Devil's Washbasin. Another study (Leitner et al., 1983) found a desert tortoise habitat associated with the *Larrea tridentata* vegetation association at Devil's Washbasin in elevations ranging from 3150 to 3700 feet. The habitat was contained in the Western Regional Wildlife Range. Another report on a field study of Devil's Washbasin (Leitner et al., 1983) found potential desert tortoise habitat (abandoned burrows) at 3100 feet on the banks of a major drainage from the northeastern slopes toward the playa in vegetation associated with *Larrea tridentata*. Desert tortoises are herbivorous, consuming low-growing vegetation. Another study (Burge and Bradley, 1976) reported that the most important plants in the diet were the annual forb (*Plantago insularis*) and the desert mallow (*Sphaeralcea ambigua*). The desert tortoise excavates and uses two kinds of burrows; one type serves as a hibernation den and the other provides shelter from high surface temperatures in summer.

There are 14 common lizard species found at Devil's Washbasin. Eleven of these are low-desert species and the other three are high-desert species. The high-desert species are found in the typical high-desert vegetation associations. These are the sagebrush lizard (*Sceloporus graciosus*), the western fence lizard (*S. occidentalis*), and the western skink (*Eumeces skiltonianus*). Most of the lizards at Devil's Washbasin are insectivores, although some are herbivores and others are omnivores. The desert iguana and chuckwalla are herbivorous, while the leopard lizard, zebra-tailed lizard, and desert spiny lizard are omnivorous. The collared lizard also eats smaller lizards in addition to insects.

Seventeen common species of snakes are found at Devil's Washbasin. They are seldom observed or collected and because of this, very little is known about population densities, habitat preferences, or activity patterns. The most common species seems to be the western shovel-nosed snake (*Chionactis occipitalis*). The sidewinder (*Crotalus cerastes*) and the speckled rattlesnake (*C. mitchellii*) are both venomous. All of the snakes are predators, eating rodents, small birds, insects, lizards, and other snakes.

A list of reptile species at Devil's Washbasin can be found in Table 5.

d. Birds

Because of the mobility of birds, their distribution at Devil's Washbasin forms a much more complex picture than that of mammals or reptiles. Flight enables birds to migrate to favorable habitats on a seasonal schedule. Because of this, the larger pattern of North American bird migration is superimposed on the pattern of mixing of the major desert biota at Devil's Washbasin. The greatest species diversity occurs in contrasting vegetation associations, pinyon-juniper and *Larrea-Ambrosia*.

There are more than 190 bird species found at Devil's Washbasin and most can be put in one of four general categories based on their migratory pattern: spring-summer resident, fall-winter resident, seasonal migrant, or year-long resident. Spring-summer residents breed at Devil's Washbasin during those seasons and then migrate south to their wintering grounds. Fall-winter residents breed in regions to the north and migrate south to winter at Devil's Washbasin. The majority of these are small passerine seed-eaters. The

TABLE 5. REPTILE SPECIES OF DEVIL'S WASHBASIN.*

Biological name	Common name
Gopherus agassizi	Desert Tortoise
Coleonyx variegatus	Banded Gecko
Dipsosaurus dorsalis	Desert Iguana
Sauromalus obesus	Chuckwalla
Callisaurus draconoides	Zebra-Tailed Lizard
Crotaphytus (Gambelia) wislizenii	Leopard Lizard
Crotaphytus collaris	Collared Lizard
Sceloporus magister	Desert Spiny Lizard
Uta stansburiana	Side-Blotched Lizard
Phrynosoma platyrhinos	Desert Horned Lizard
Xantusia vigilis	Desert Night Lizard
Cnemidophorus tigris	Western Whiptail
Tantilla utahensis	Utah Black-Headed Snake
Hypsiglena torquata	Night Snake
Crotalus mitcheli	Speckled Rattlesnake
Crotalus cerastes	Sidewinder
Leptotyphlops humilis	Western Blind Snake
Diadophis punctatus	Ringneck Snake
Phyllorhynchus decurtatus	Leaf-Nosed Snake
Masticophis flagellum	Coachwhip
Masticophis taeniatus	Striped Whipsnake
Salvadora hexalepis	Patch-Nosed Snake
Arizona elegans	Glossy Snake
Pituophis melanolecus	Gopher Snake
Lampropeltis getulus	Common Kingsnake
Rhinocheilus lecontei	Long-Nosed Snake
Sonora semiannulata	Western Groundsnake
Chionactis occipitalis	Western Shovel-Nosed Snake
Trimorphodon lambda	Sonora Lyre Snake

* Patton et al., 1986.

primary seeds consumed are those of the Russian thistle (*Salsola* sp.). Each spring and fall, large numbers of migrants pass through Devil's Washbasin. These birds are moving between their more northerly breeding grounds and their wintering areas to the south. Many are waterfowl that are attracted to the few areas of water along their migration routes. Some stop at Grand Island Creek or on the playa itself when it is flooded by winter runoff. All residents of the year-round category breed at Devil's Washbasin.

Some bird species found at Devil's Washbasin are listed in Table 6.

e. Mammals

There are 46 species of mammals known at Devil's Washbasin and almost half of these are rodents. Other mammals common to Devil's Washbasin include mule deer, three species of bats, two species of rabbits, and four carnivores. Rodents are the most important group of mammals at Devil's Washbasin in terms of biomass and species diversity. The densities of rodent populations are highly variable from year to year. High rainfall years, with a large production of winter annual vegetation, lead to higher reproductive success and higher rodent densities in the following spring and summer. The two rabbit species are herbivores, and their populations probably fluctuate with the production of winter annuals, though not as markedly as do the rodent populations. All of the bat species are insectivores.

Several species of large herbivores are found on or near Devil's Washbasin. The most common is the mule deer (*Odocoileus hemionus*). These animals usually inhabit the northern higher mesas, but come down to lower elevations during the winter. There are no confirmed sightings of desert bighorn sheep at Devil's Washbasin, although they do occur to the east on the Western Regional Wildlife Range. In addition, they will migrate through adjacent areas in the fall and early spring when water is available. The US Fish and Wildlife Service may introduce water into these adjacent areas in the future to bring sheep into the area on a year-round basis.

At the top of the food chain are the mammalian predators: coyote (*Canis latrans*), kit fox (*Vulpes macrotis*), badger (*Taxidea taxus*), bobcat (*Lynx rufus*), and long-tailed weasel (*Mustela frenata*). They may range through all vegetation associations at Devil's Washbasin. The coyote has a catholic diet

TABLE 6. BIRDS COMMON TO DEVIL'S WASHBASIN.*

RESIDENTS	SPRING/SUMMER
Red-Tailed Hawk	Turkey Vulture
Golden Eagle	Mourning Dove
Marsh Hawk	Western Kingbird
Sparrow Hawk	Black-Throated Sparrow
Prairie Falcon	Chipping Sparrow
Rough-Legged Hawk	
Roadrunner	MIGRATORY
Burrowing Owl	Pintail
Sparrow	American Widgeon
Say's Phoege	Green-Winged Teal
Horned Lark	Cinnamon Teal
Common Raven	Canada Goose
Common Bushtit	Shoveler
Cactus Wren	Common Snipe
Mockingbird	
American Coot	WINTER/FALL
Loggerhead Shrike	House Finch
House Finch	Sage
Killdeer	White-Crowned Sparrow
Chucker	Starling
Sage Thrasher	
Le Conte's Thrasher	
Red-Winged Blackbird	

* Patton et al., 1986.

and is found throughout Devil's Washbasin, often reflecting the distribution of the mule deer. It is the most commonly observed predator in the area. Badgers and long-tailed weasels are secretive and rarely seen. Mule deer, coyotes, and bobcats have been observed at Devil's Washbasin with the coyotes being observed on the playa.

A complete list of mammal species at Devil's Washbasin can be found in Table 7.

Third, the impact that testing will have on the habitat constraints and natural succession should be predicted.

The playa at Devil's Washbasin is barren during the summer and does not support any wildlife. Very few vertebrates are likely to be active on the surface in the *Atriplex* association from late morning to late afternoon. A few species of lizards, snakes, rodents, and small birds, as well as black-tailed jackrabbits, could be exposed to potentially toxic smoke concentrations, however. The number of individuals at risk is unknown. The habitat area that could be affected by the smoke test is small in relation to the total area of similar habitat at Devil's Washbasin. In addition, the species that are likely to be exposed are widespread and abundant, and any deaths would be rapidly compensated through reproduction and migration from the surrounding habitat. Burrow-dwelling vertebrates are expected to be underground at the time of day when the test takes place and many wildlife species normally plug the entrance to their burrows with loose dirt. This physical barrier would prevent any exposure to potentially harmful gas concentrations. It is unlikely that burrows that are not plugged would be affected because of the temperature difference between the burrow air and the gas cloud.

The only expected impact on animal populations should be mild respiratory tract irritation and possibly minor, reversible, lung damage.

Fourth, whether any endangered or protected species will be affected by the tests should be determined.

The desert tortoise has been listed as a protected species by the state board of Fish and Game Commissioners. The species is currently being reviewed by the US Fish and Wildlife Service for protection under the

TABLE 7. MAMMAL SPECIES COMMON TO DEVIL'S WASHBASIN.*

Biological name	Common name
Canis latrans	Coyote
Lynx rufus	Bobcat
Odocoileus hemionus	Mule Deer
Mustela frenata	Long-Tailed Weasel
Spilogale gracilis	Western Spotted Skunk
Taxidea taxus	Badger
Thomomys umbrinus	Southern Pocket Gopher
Lepus californicus	Black-Tailed Jackrabbit
Sylvilagus audubonii	Desert Cottontail
Dipodomys deserti	Desert Kangaroo Rat
Dipodomys merriami	Merriam's Kangaroo Rat
Dipodomys microps	Great Basin Kangaroo Rat
Spermophilus terticaudus	Round-Tailed Ground Squirrel
Ammospermophilus leucurus	White-Tailed Antelope Squirrel
Neotoma lepida	Desert Wood Rat
Onychomys torridus	Southern Grasshopper Mouse
Peromyscus eremicus	Cactus Mouse
Perognathus formosus	Long-Tailed Pocket Mouse
Antrozous pallidus	Pallid Bat
Pipistrillus hesperus	Western Pipistrelle (Bat)
Myotis californicus	California Myotis (Bat)

* Patton et al., 1986.

Endangered Species Act of 1973. One species of desert tortoise found in the western United States, the Beaver Dam Slope desert tortoise has already been placed on the federal threatened species list.

Downwind smoke concentrations would be relatively low in the desert tortoise habitat. In addition, these animals are nocturnal and would be expected to be in their burrows at the time the tests are carried out.

There are no known birds regularly found at Devil's Washbasin that are currently listed as threatened or endangered under the federal Endangered Species Act of 1973. A few recent sightings of the endangered American peregrine falcon (*Falco peregrinus anatum*) at Devil's Washbasin probably involved transient individuals. All birds of prey (Order Falconiformes: vultures, hawks, and falcons, and Order Strigiformes: owls) and the roadrunner are fully protected under state law and may be present at Devil's Washbasin.

Kit foxes are currently listed on the federal Endangered Species List. They have not been observed at Devil's Washbasin since 1983.

C. CULTURAL AND SOCIOECONOMIC CONDITIONS

A number of steps need to be followed to adequately assess the cultural and socioeconomic conditions at the test site.

1. Culture

Laws and regulations governing the preservation of cultural resources have been evolving in recent years. Most states have laws that regulate the disturbance of cultural resources on state land. Some of these state laws are quite aggressive, but there is considerable variation between states. It will be necessary to evaluate state and local ordinances before beginning the assessment of cultural resources.

The cultural resources, their significance, and the impacts that testing will have on them should be identified.

C. CULTURAL AND SOCIOECONOMIC CONDITIONS

1. Culture

Human occupation of Devil's Washbasin and its environs dates back to about 10,000 B.C. A number of aboriginal hunting and gathering cultures were present during this long prehistorical period. The area was occupied by the Paiutes when the first European settlers entered Devil's Washbasin. From about 1849 until the establishment of the installation at the site, the land was used mainly for livestock grazing and mining.

Investigations of archaeological and historical features of Devil's Washbasin have resulted in the identification of numerous archaeological sites and several sites having historical interest. These sites have been recorded in the Site Record File of the State Museum. None of these sites have been placed on the National Register of Historic Places and none are believed to meet the criteria for nomination for inclusion in the National Register.

Both historic and prehistoric sites at Devil's Washbasin tend to be located near springs, in canyons, and at or near the bases of mountains. The larger valleys show little sign of early human occupation. No archaeological or historic sites have been reported at the actual test area or in the surrounding area, and it is extremely unlikely that they exist there.

2. Land Use

Land use should be described. This will include a narrative history of the use of the land, including both military and civilian use.

2. Land Use

The land area at the Devil's Washbasin site consists of a little more than 1,500 square miles or 963,873 acres. All of the land at the installation is used, with about 85% of the acreage being used as maneuver areas for training operations such as the smoke tests, buffer safety zones, or artillery impact areas.

NASA and several other government agencies maintain formal land use agreements with the Army for various land-related activities.

a. Facilities. The permanent party stationed at Devil's Washbasin is a US Army headquarters unit that has authorization for 162 military personnel and for 14 civilians, who administer the post exchange club system facilities at the southwest corner of the site (Fig. 3).

Between 2,000 and 4,000 Regular US Army and US Army Reserve personnel currently use Devil's Washbasin during each of 52 training weeks per year. (Training occurs year round.) During training, from 12,000 to 15,000 troops will rotate through Devil's Washbasin in five training sessions.

The active Army regularly uses the Devil's Washbasin site for armored exercises.

NASA maintains its Silver Lake Deep Space Communications Complex on 68 square miles on the northwestern portion of the installation. There are 285 people employed at the complex. Electronic frequency interference from military warfare equipment used at the site is a problem.

The US Air Force uses the Buffalo Valley Air-to-Ground Gunnery Range for gunnery activities throughout the year, and the Badger Lake Army Air Field and Johnson Airfield are located at the southwestern corner of the playa.

b. Airspace. The airspace over Devil's Washbasin is restricted from ground level to infinity. The US Air Force currently uses it for daily air-to-air and air-to-ground firing at the west end of the installation. NASA's Silver Lake Tracking station continually operates radar and the US Army uses the rest of the airspace for training sessions. A supersonic air corridor passes over the southern portion of the site.

3. Economy

An analysis of the economy should include regional economics, population, employment, and housing.

3. Economy

a. Regional Economics. In the past, the economies of the town of Wildwood and the community of Buffalo have been based on their location and relative isolation. Historically, mining, ranching, and grazing

have been the major industries. Today, their proximity to military training centers has helped to stabilize the economies of these two communities.

b. Population. The town of Wildwood has a current population of 13,240 and the town of Buffalo has a population of 422. Both communities have experienced a 3% decline in population over the last ten years, but this decline is not seen as significant.

c. Employment. Employment in the Wildwood Unified School District and the Community Hospital has declined to reflect the decline in population. Overall, the unemployment rate for the two areas is at 4%.

d. Housing. There was some new housing construction in Wildwood in 1977, but since then, new housing starts have dropped off. Approximately 37% of the housing in Wildwood and 14% of the housing in Buffalo are rentals.

4. Government, Social, and Institutional Conditions

An analysis of the government, institutional, and social conditions of the area will include a description of health and education facilities, parks and recreation, public safety, fire protection, transportation, and public infrastructure.

4. Government, Social, and Institutional Conditions

The town of Wildwood is incorporated and maintains many of its own community services. Buffalo is unincorporated and receives its services from county agencies.

a. Health Facilities. Wildwood has a representative group of medical services. There is a general hospital and a convalescent hospital, three pharmacies, and an ambulance service. There are currently seven physicians in private practice, four dentists, and an optometrist. There are no health facilities at Buffalo, although there is a physician in private practice there.

b. Education. The major educational institution in Wildwood is the Wildwood Unified School District. Grand Island Community College also operates a branch campus at Wildwood. There is an enrollment of 1578 students in the district with an employment of 148 staff and supervisory personnel.

c. Parks and Recreation. Wildwood City Park Department operates

42 acres of parks within the city limits. There are plans to include additions to the park areas.

d. Public Safety. Wildwood opearates its own police department with 16 personnel and 5 patrol cars. The County Sheriff's Department provides public safety for the Buffalo area.

e. Fire Protection. The Wildwood Volunteer Fire Department covers 15 square miles and approximately 13,000 people. It also serves the community of Buffalo.

f. Transportation. State Highway 47 runs through the town of Wildwood and is the main north-south access road in the area. Two major railroads pass through Wildwood.

g. Infrastructure. The town of Wildwood receives its water through a pipeline from the Crystal River. There is a major municipal wastewater collection and disposal system outside of Wildwood and nearly 87% of the residents of the town receive sewer service from the system.

5. Aesthetics

A brief description of the aesthetics of the area should include any designation by the US Bureau of Land Management.

5. Aesthetics

The US Bureau of Land Management has designated the mountains around Devil's Washbasin to be of "prime" scenic quality. The rest of the site has been designated as "common."

6. Electromagnetic Interference

A determination should be made as to whether the radios, radar, and electromagnetic warfare used on the installation will interfere with non-cable and FM radio transmission.

6. Electromagnetic Interference

The electronic military warfare equipment used in training exercises at the site creates a problem of frequency interference both with commercial

media and the NASA tracking station. The Department of Defense Electromagnetic Compatibility Analysis Center in Annapolis, Maryland, is currently conducting an analysis for the area and will recommend specific frequency assignments, operating locations, and times of operation.

IV. PHYSICAL, CHEMICAL, AND BIOLOGICAL PROPERTIES OF WHITE PHOSPHORUS/FELT WEDGES

To adequately assess the environment of the test area and the impacts of the smoke on that environment, it will be necessary to analyze the individual smoke product and its reaction products.

A. PHYSICAL AND CHEMICAL PROPERTIES

Characteristic physical and chemical properties should be described, including the smoke and the device used to produce it. Tables 2, 3, and 4 in Volume I list the chemical and physical properties of elemental white phosphorus, phosphoric acid, and phosphorus pentoxide respectively.

IV. PHYSICAL, CHEMICAL, AND BIOLOGICAL PROPERTIES OF WHITE PHOSPHORUS/FELT WEDGES

A. PHYSICAL AND CHEMICAL PROPERTIES

1. The Munition

A white phosphorus/felt wedge munition (WP/FW) is a felt wedge that is impregnated with white phosphorus. The munition is a cylindrical assembly approximately 22 inches long and 5 inches in diameter containing 4 disks. Each disk contains wedge-shaped white-phosphorus-felt smoke generators. The entire assembly is propelled into the test area and activated, releasing and scattering the 128 wedges. When it is deployed, a central burster charge separates the wedges. Smoke will be produced continually for 7 minutes. The munition to be used in this test is the M259 2.75-inch WP wedge rocket.

2. Fill and Sub-Munition Chemical Composition

White phosphorus is a crystalline network of elemental phosphorus. It is prepared commercially by roasting phosphate ores with silica and coke in an electric furnace. Phosphorus pentoxide is formed when the silica reacts with the phosphate ore. The coke then reduces the phosphorus pentoxide to white phosphorus.

The phosphorus that is released by this reaction is a vapor. This vapor is then cooled and condensed under water to produce solid white phosphorus. In this state it is a yellowish, waxy solid that looks like paraffin and melts to a straw-colored liquid. The final product may contain small amounts of arsenic and hydrocarbons as contaminants.

3. Chemical Properties of White Phosphorus

White phosphorus reacts spontaneously with air to produce phosphorus oxides. Because it is highly reactive with oxygen, it is used to advantage in bursting munitions such as mortar rounds, artillery, and grenades. However, this same reactive property can present a hazard to personnel, and it is necessary to handle it with caution.

The most important phosphorus oxide produced in the reaction with oxygen is phosphoric pentoxide, which is responsible for the dense white cloud that is produced when the WP/FW is ignited. When phosphoric pentoxide and the other major oxide of phosphorus, phosphorus trioxide, come into contact with atmospheric moisture, they become phosphoric acid and phosphorous acid. These are both powerful dehydrating agents.

4. Size and Release Characteristics

When white phosphorus is ignited, the phosphorus breaks up into minute particles, which are dispersed over a large area. The diameter of the particles is generally around 1 μm. The ignition and rapid oxidation of these minute particles of phosphorus creates a large amount of heat and causes the pillar of smoke to rise.

In addition, the phosphorus oxides, which are formed from the reaction of white phosphorus and air, in turn react with water vapor in the air and

form various phosphoric acids. The molecules of phosphoric acid, because of their greater size, are the more effective obscurant. White phosphorus smoke is an aerosol that blocks a portion of the visual light spectrum.

5. Atmospheric Concentration

Each WP/FW produces a dense cloud of white smoke, which consists primarily of phosphorus oxides. An initial average smoke concentration of about 3100 mg/m^3 will occur from each M2 munition over a minimum impact area of 516 m^2. By selecting appropriate stability categories, environmentally significant concentrations in excess of 25 mg/m^3 will extend not more than 1 km downwind.

B. ENVIRONMENTAL CHEMISTRY

The discussion of environmental chemistry will include descriptions of chemical transformations in soil, water, and plants.

B. ENVIRONMENTAL CHEMISTRY

1. Soil

Unreacted white phosphorus in soil systems may be oxidized to phosphates over a period of weeks to months. The high alkaline content of the soil at Devil's Washbasin will increase the rate of decomposition, however. The alkaline soil and the electropositive metals (such as aluminum) found on the playa may combine with any unreacted phosphorus to form the corresponding phosphides. The unreacted phosphorus might also react with the alkali hydroxides in the soil to form phosphine and hypophosphites. The amount of oxygen in the soil will also determine the rate of transformation of white phosphorus in the Devil's Washbasin soil. It may remain for months in an anaerobic sediment at the bottom of a pool of standing water.

White phosphorus is predominately transformed to phosphates. These phosphates are plant nutrients and will be incorporated into the ecosystem by plant uptake.

Fallout from the production of WP/FW smoke will be predominately phosphoric acid. There is a high ammonia content in the Devil's Washbasin soil. This ammonia will react with phosphoric acid to produce ammonium salt, which can be utilized by plants and other biota as a source of phosphorus. The phosphoric acid will also react with the alkali hydroxide in the Devil's Washbasin soil to produce organic phosphate salts and will react with aluminum and other metals in the soil to form inorganic metal phosphates.

2. Water

Phosphoric acid and phosphorous acid will be produced through the reaction of the oxides of phosphorus with atmospheric moisture. These products will not be further transformed upon contact with the water in an aquatic system. The small amount of unreacted phosphorus from the smoke cloud, however, will be rapidly oxidized upon contact with water and will be transformed into hypophosphorous acid and phosphorous acid.

Because white phosphorus is only slightly soluble in water, it would probably reach an aquatic system through dry deposition, such as that from unreacted WP in the felt wedges. Dissolved oxygen in the water will react with dissolved or undissolved WP to form lower oxyacids of phosphorus. Eventually, over a period of weeks to months, the WP will be oxidized to phosphates. The phosphates will be partitioned between the sediments and aqueous phase, 90% and 10% respectively (Edzwald, 1977). Phosphates are an essential plant nutrient and their introduction into an aquatic system can result in an "algal bloom."

White phosphorus can remain for long periods in the anaerobic sediment found at the bottom of standing pools of water on the Devil's Washbasin playa. This can present a problem when the water evaporates and the phosphorus comes into contact with the oxygen in the air.

If the phosphoric acid is deposited in the sediment of the creek bed it can result in a long-term phosphate source for the biota of the creek. The most serious impact to Grand Island Creek would result if the great amount of precipitation resulting from a desert thunderstorm were to cause a washout of

the phosphoric acid deposited on the uphill vegetation. This would result in the introduction of potentially toxic amounts of phosphoric acid into the creek.

V. IMPACT CRITERIA

Army Regulation 200-2 and the NEPA process require that all applicable legal standards and requirements be met. The standards and requirements generally pertain to air quality, water quality, biological resources, and/or land use. The discussion of impact criteria for air quality and water quality should include a comparison of the reaction products of the smoke to local, state, and federal air quality and water quality standards.

V. IMPACT CRITERIA

A. AIR QUALITY

The Federal Clean Air Act (CAA) of 1977 established a program for the creation of air quality standards. This program was begun because of public concern about the health aspects of air pollution. The CAA includes National Ambient Air Quality Standards (NAAQS) to control particular criteria air pollutants and to protect human health and the environment.

Under the CAA, the country is divided into Air Quality Control Regions (AQCR), which provide basic geographic areas for the control of air pollution. Each state in which a region is located is required to prepare a State Implementation Plan (SIP) to implement and enforce criteria pollutant standards in each AQCR.

The proposed site for the testing of WP/FW at Devil's Washbasin is approximately 75 km north of the community of Buffalo and 90 km northeast of the town of Wildwood. Since the prevailing wind direction is from the southwest, it is, therefore, unlikely that ambient concentrations of the major air pollutants from the tests will have any significant impact on the air quality of these communities.

The proposed testing of WP/FW at Devil's Washbasin will meet the state and federal air quality standards for the major pollutants and general

ambient-air emission guidelines. These standards and guidelines will not be exceeded at any point accessible to the public, or at any other location outside of the geographic boundaries of the test site.

B. WATER QUALITY

The Federal Water Pollution Control Act (FWPCA) of 1972 established basic water quality goals and policies for the country. It is commonly known as the Clean Water Act. The Environmental Protection Agency has developed regulations under the FWPCA that identify and establish reporting requirements for 270 hazardous substances. Phosphorus is one of the most strictly regulated substances with a reporting quantity of 1 pound. Phosphoric acid is also a regulated substance with a reporting quantity of 5,000 pounds.

There is not expected to be any impact on water resources from the testing of WP/FW at the Devil's Washbasin site. Groundwater resources will not be affected in any way by the tests because an impervious layer underlies the playa and the groundwater is 200 m below the surface. The only surface water that could be affected by the tests is the water in Grand Island Creek or the water on the playa itself during the rainy season. The creek is in the path of the wind that will be carrying the smoke cloud, but is nearly 40 km away from the site of ignition. It is expected that the atmospheric concentration of phosphorus smoke will be diluted to such an extent by the time it reaches the creek that any impact would be insignificant or negligible.

Phosphoric acid concentrations will be relatively high in the area of the playa, but it is not expected to leave any significant residual in the standing water on the playa. Of concern, however, would be the residual of unreacted phosphorus, which can be expected to be about 1% of the smoke mix. If this residual falls into the water of the playa, it would result in water concentrations of 0.43 g/m^3. This level is 10,000 times higher than what is considered safe for aquatic organisms. Because of this, it is imperative that the tests not be conducted near any bodies of water. The standing water on the Devil's Washbasin playa supports only small populations of insects, but it would nevertheless be important to restrict the tests to areas that would not receive any residual from the operation.

C. BIOLOGICAL RESOURCES

The discussion of impact criteria for biological resources should include an analysis of direct impacts and of the bioeffects and toxicology of the smoke with respect to any species in the area that are protected by the federal Endangered Species Act of 1973 or any state laws protecting rare or threatened species.

C. BIOLOGICAL RESOURCES

Various species of fish, wildlife, and plants in the United States have already become extinct as a result of economic growth and development that was unconcerned with environmental conservation. Other species have had their numbers so depleted that they are in danger of becoming extinct. Because of this, the Endangered Species Act of 1973 was passed. This act was established for the purpose of protecting all species of wildlife and plants that are threatened or endangered. Also protected by the Act are the habitats of threatened or endangered species.

The primary impacts on wildlife populations at the Devil's Washbasin site would be the result of ingestion of unreacted phosphorus or vegetation on which phosphoric acid has been deposited. Animals that ingest these materials could receive potentially lethal doses of the unreacted material and toxic amounts of phosphoric acid. Those animals most likely to be affected would be coyotes, migratory waterfowl, lizards, snakes, rodents, and black-tailed jackrabbits. In summer, burrowing species would not be affected by the smoke cloud because they plug the entrance to their burrow during the day.

One animal at the Devil's Washbasin site is on the federal Endangered Species List; the desert tortoise. The desert tortoise is nocturnal and is expected to remain in its burrow during the time the tests take place. None of the testing is expected to alter or disrupt the desert tortoise habitat. While the kit fox is on the Endangered Species List and potential habitats for the kit fox are present, it has not been observed at the site since 1983. Moreover, the testing is not expected to affect the kit fox habitat.

There are no threatened or endangered plant species at the Devil's Washbasin site, but the *Atriplex* association at the edge of the playa is of

concern. This vegetation supports a large variety of wildlife and if it is burned or contaminated by phosphoric acid, numerous habitats could be disrupted or destroyed.

D. LAND USE

It will be necessary to identify any possible conflicts that will arise between the testing and federal, regional, state, and local (including tribes of native Americans) land use plans, policies, and controls for the area of the test.

D. LAND USE

The testing of WP/FW at Devil's Washbasin will have potential impacts on the US Army and US Air Force operations at the installation. Consideration should be given to potential noise and range-fire impacts.

In general, however, it is not expected that the tests will have a significant impact on the land use of the area. The tests will be confined to geographic areas that are within the boundaries of the installation itself and are specifically intended for Army training exercises.

VI. IDENTIFICATION OF ENVIRONMENTAL EFFECTS

The purpose of S&O is to obscure the air. The S&O materials then settle from the air onto water, land, and vegetation. Consequently, the identification of environmental effects must begin with a determination of the concentration and dispersion of the smoke in air. The results of this determination can be used to estimate the deposits on water, soil, and vegetation and the resulting effects on wildlife, vegetation, and people.

In this hypothetical EA the dispersion of S&O materials was modeled. However, dispersion can also be estimated using the methods discussed in Section II.A.2. on Air Quality.

VI. IDENTIFICATION OF ENVIRONMENTAL EFFECTS

A. AIR QUALITY

To adequately assess the impact of the testing of WP/FW on the environment of the Devil's Washbasin site, the computer modeling system HAZRD2 was used. This enables the prediction of the environmental effects of the tests on the area.

To determine the area affected by hazardous concentrations of the tested materials, the HAZRD2 model was run under a variety of atmospheric conditions using an interim threshold value (ITV). The ITV is equal to 1% of the LC_{50} for each munition (Shinn et al., 1985, Table 5). This threshold concentration for each munition cannot be exceeded at the boundary of the test area for any test. The results of these runs were used to determine the lateral and downwind distances required for tests. Because the area set aside for tests at Devil's Washbasin has a downwind distance of 20 km, certain atmospheric conditions had to be eliminated from the test plan. The eliminated conditions are those of very stable atmospheric conditions and low wind speeds, because concentrations of the material exceeding the ITV would carry past the area set aside for the tests under these conditions.

To confine the smoke cloud and its impacts to a particular geographic area, it is necessary to determine the persistence of wind direction under certain meteorological conditions. Meteorological data for Devil's Washbasin that were obtained from the National Climatic Data Center were inserted into the HAZRD2 system. These data were the 15-year period from 1965 to 1980 and contained information on frequencies of wind speed, wind direction, height of the mixing zone, and atmospheric stability conditions. The data were collected by the US Army using a 62-m meteorological tower, which had instruments at 3, 10, 30 and 60 m, and by several portable stations (DW1 through DW4 and Sharmer Bunker, see Fig. 13). Wind direction, wind speed, standard deviation of wind direction, vertical turbulence, temperature, humidity, and barometric pressure were recorded. Each sensor was sampled once per second and a microprocessor-based data-acquisition system made it possible to obtain on-line calculations of the turbulent wind fluctuations and the mean values used in atmospheric stability indices. A data base that included 3-minute as well as hourly summaries was used.

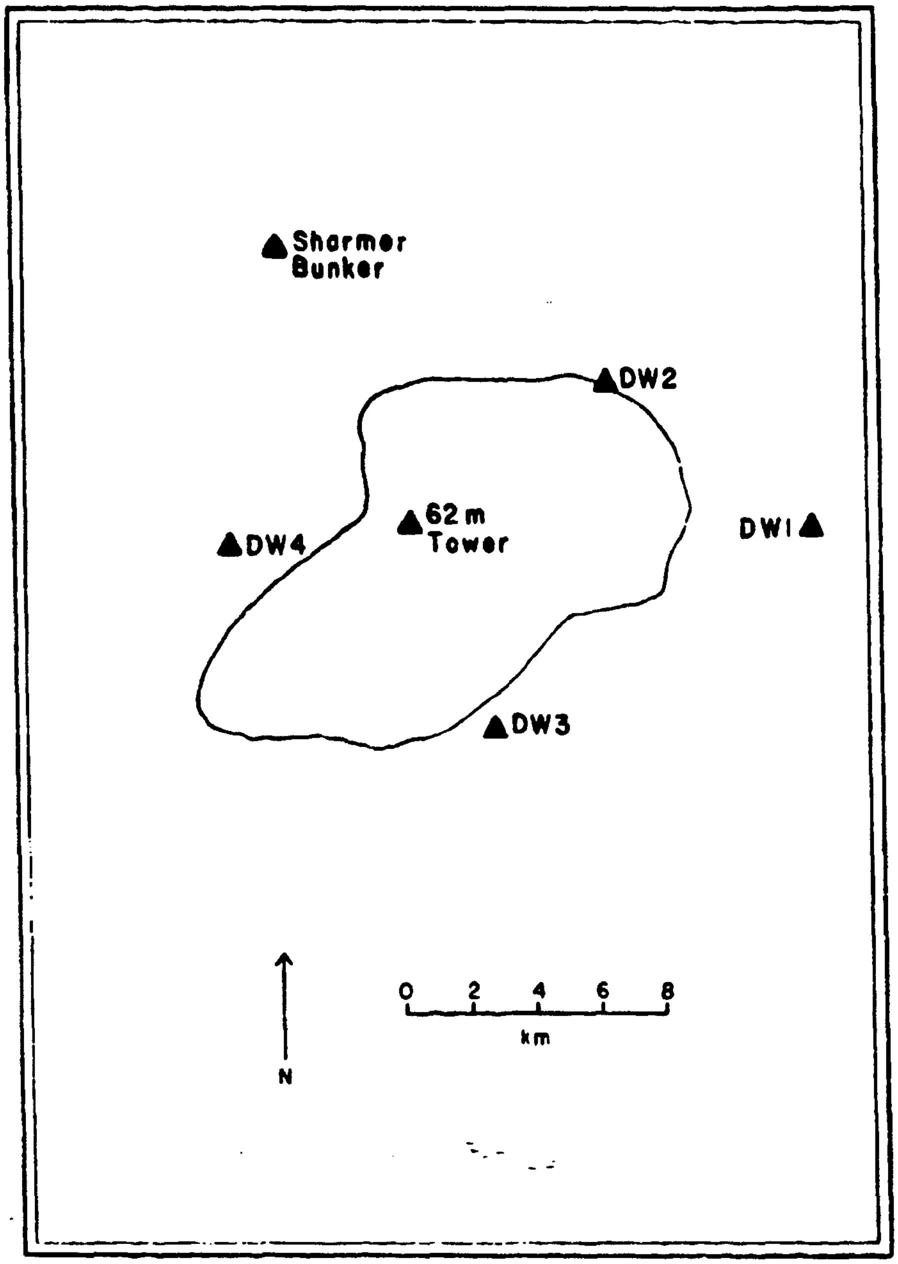

Figure 13. Meteorological stations used in gathering data at Devil's Washbasin.

Based on this information, it can be concluded that the wind direction at Devil's Washbasin is predictably and regularly from the southwest (225 degrees) between March and September (Fig. 14). The wind direction prevails at about 225 degrees with very little deviation and with a variety of speeds and associated atmospheric stabilities.

A study by the US Army was conducted to determine the possibility of wind-direction meander after the smoke is ignited. The test criteria included daytime tests when the wind direction is within 10 degrees of the sensor array center line (225 degrees), wind speeds of 2 to 8 m/sec, and intensity of turbulence (standard deviation of wind direction) less than 30 degrees for 9 minutes prior to the test. It was found that in less than 3% of all hypothetical test cases did the cloud meander more than 30 degrees from the array center line (Fig. 15).

Wind speed and turbulence should be accounted for in the determination of the dispersion properties of the smoke cloud. The wind speed will transport the cloud downwind, while the turbulence will spread and dilute the cloud. The atmospheric stability and the surface roughness determine the value of the standard deviation of mean wind direction for a 3-minute period. The atmospheric stability classes are generally classified in ranges from A to F with A being very unstable and F being very stable.

B. SOIL DEPOSITION

Because the fallout from the production of WP/FW smoke will be predominantly phosphoric acid, the depositions of this compound should be determined. In estimating the deposition of phosphoric acid in soil and soil products, it is necessary to multiply the velocity of the smoke materials (3.6 m/h) (Shinn et al., 1985) times the airborne concentration times the fraction of an hour that the tests will take place. This will equal deposition as milligrams per square meter (mg/m^2).

The downwind airborne concentrations of phosphoric acid as a result of an M259 test (Yon et al., 1983) are the following:

1. 100 m - 146 mg/m^3.
2. 500 m - 22.6 mg/m^3.
3. 1000 m - 9.42 mg/m^3.
4. 5000 m - 0.963 mg/m^3.

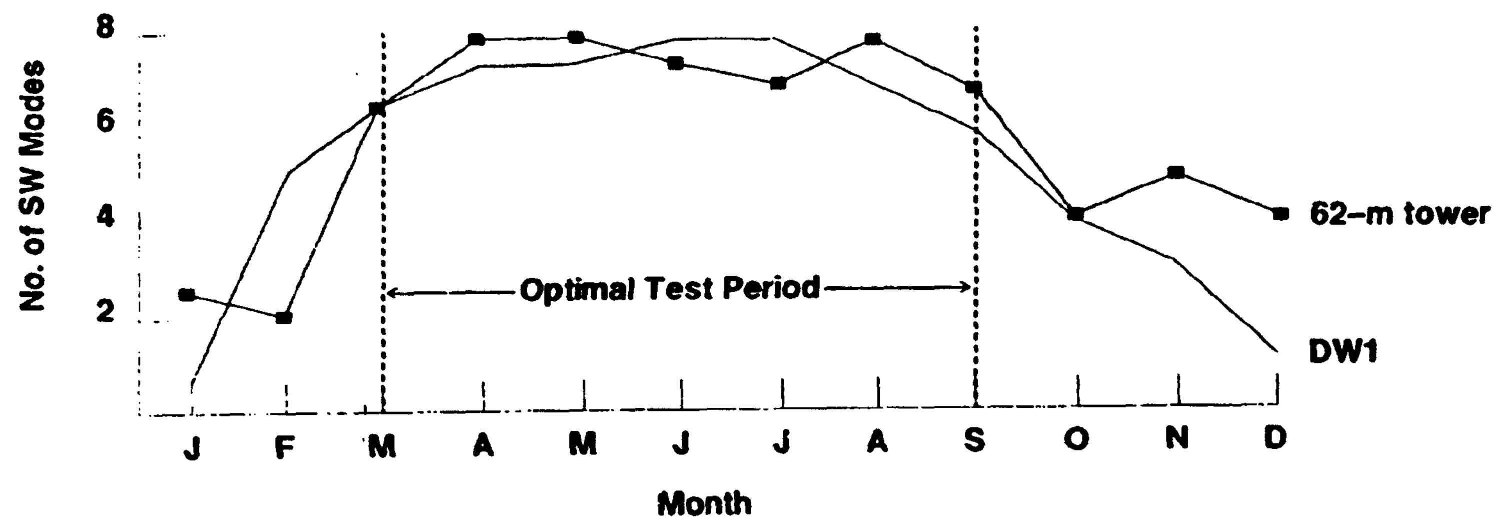

Figure 14. Optimal period for smoke tests at Devil's Washbasin as determined through analysis of on-site meteorological conditions.

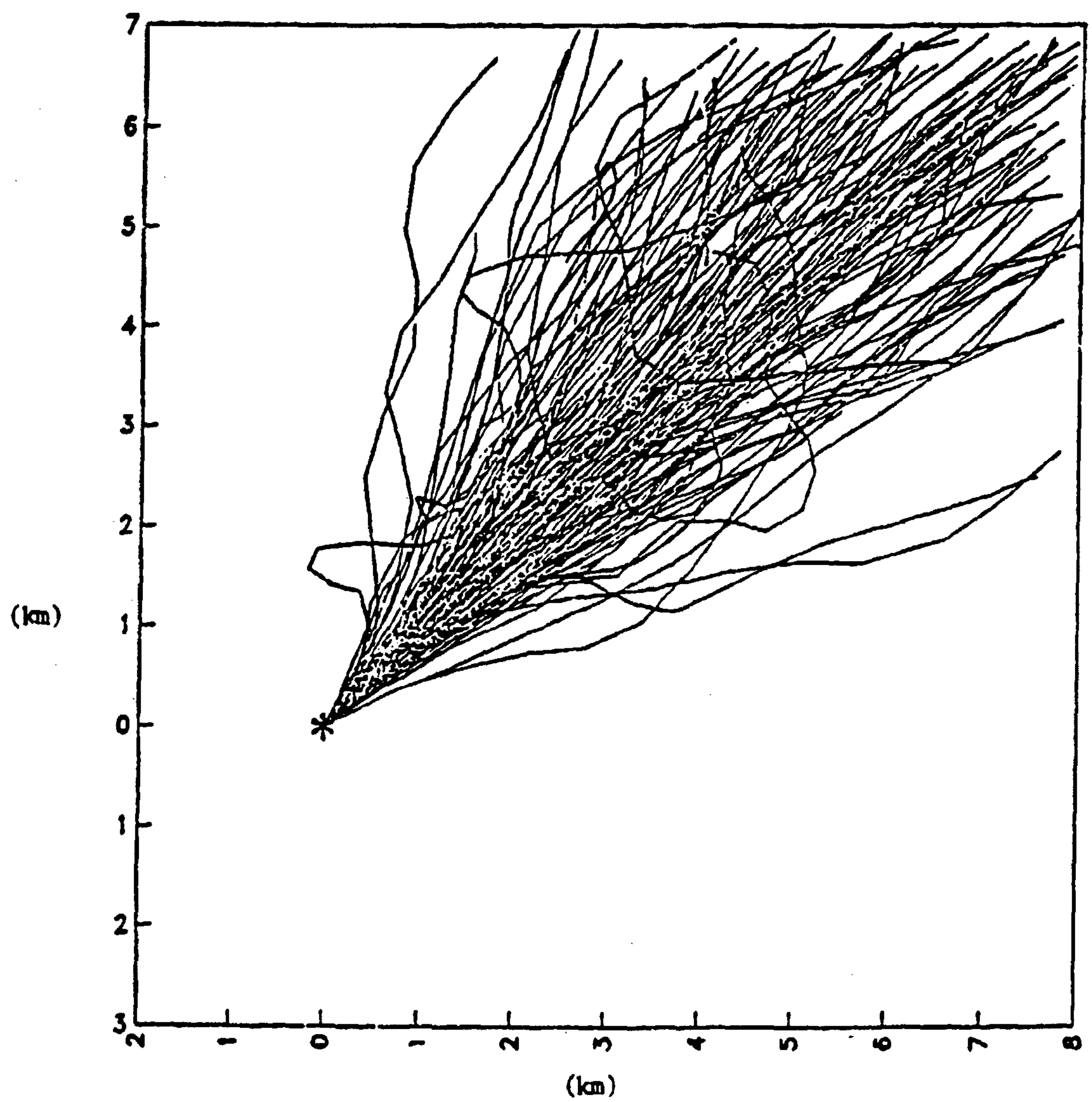

Figure 15. Trajectories of 144 cases of simulated tests subsequent to meeting test criteria: wind direction within 10° of 225°, wind speed between 2 and 8 m/sec, and standard deviation of wind direction less than 30° (9 minutes prior to test).

The following would therefore be the soil depositions:

1. At 100 m downwind - (146) x (3.6) x (1) = 525.6 mg/m^2/h.
2. At 500 m downwind - (22.6) x (3.6) x (1) = 81.36 mg/m^2/h.
3. At 1000 m downwind - (9.42) x (3.6) x (1) = 33.912 mg/m^2/h.
4. At 5000 m downwind - (0.963) x (3.6) x (1) = 3.467 mg/m^2/h.

The high alkalinity and the presence of metals such as aluminum in the soil at Devil's Washbasin will serve to rapidly break up and immobilize the reaction products of the WP/FW. They may also be absorbed by soil particles and plants in the ecosystem.

The deposition of S&O on soils is estimated by multiplying the estimated deposition velocity of S&O particles in the atmosphere (3.6 m/hour) by MAC, the airborne concentration (mg/m^3 of air), by T, the fraction of an hour the concentration is maintained. Deposition equals 11,160 mg/m^2. Smoke residue may be assumed to be incorporated into the top 5 cm of undisturbed soil and into the top 15 cm for tilled soil.

C. WATER QUALITY

The deposition of phosphoric acid in water is calculated in essentially the same manner as for soil. The deposition on surface water is calculated by multiplying the velocity of the aerosol particles in the atmosphere (3.6 m/h) times the airborne concentration (C) times the fraction of an hour (T) that the concentration is maintained. The deposition (D) in mg/m^2 is (3.6) x (C) x (T).

D. BIOEFFECTS AND TOXICOLOGY

The section on the toxic effects of smoke products on the non-human biota of an ecosystem should begin with a brief narrative concerning toxic effects. The data should then be presented according to the toxic effects on both aquatic systems and terrestrial systems.

D. BIOEFFECTS AND TOXICOLOGY

Because of the highly reactive nature of phosphorus, it has been difficult to accurately quantify its toxicity. The US Army has sponsored much research in the last ten years on the potential acute toxicity of white

phosphorus smoke and the effects on aquatic organisms in particular. There also has been extensive research on the acute toxicity and acute inhalation of phosphorus by laboratory animals, but there is a lack of information about the toxic effects of WP on other animals. There is also a lack of information about the potential chronic toxicity thresholds for terrestrial organisms for the various exposure routes. Most of the current data on white phosphorus exposure to organisms in the environment is based on field observations and is qualitative in nature.

However, to adequately assess the immediate acute effects and the long-term chronic effects of testing phosphorus smoke, it is necessary to predict as accurately as possible the consequences of introducing into the ecosystem both the initially deposited compounds and their more stable transformed compounds.

1. Aquatic Systems

In water, phosphorus can be relatively insoluble; its solubility is dependent upon the dissolved oxygen, temperature, and pH of the water. When dissolved, the oxidation products will be phosphorous acid and phosphoric acid.

While the reaction products of phosphorus smokes have a generally low toxicity to aquatic organisms, the most serious problem in aquatic systems is not the toxicity of the products, but rather their nutritive quality. These products act as a fertilizer in water and may cause an "algal bloom." The plants in the system may grow so rapidly that the microorganisms that decompose them use up most of the oxygen in the water during the work of decomposition. This, in turn, would create a serious lack of dissolved oxygen in the water and could possibly result in a fish kill. This hazard would not be a problem at the Devil's Washbasin site because the water that pools on the floor of the playa does not remain long enough, and the fast moving current of Grand Island Creek would not support the growth of algae. The only reaction product of WP/FW smoke that could be potentially toxic to aquatic organisms would be phosphine. It may have some adverse effects on finfish at concentrations of 3 to 6 ppm.

A recent study (Sullivan et al., 1979) demonstrated the effects of WP on aquatic organisms. The study showed that the portions of WP that remain in

the water as elemental phosphorus are acutely toxic to aquatic organisms at very low concentrations. The 96-hour threshold limit median (TLM-96) for exposure to finfish is generally from 2 to 154 g/L. The range for bluegill is 1 to 4 g/L and is just 0.4 g/L for fathead minnows. The 50% lethal concentration (LC_{50}) range for algae and aquatic invertebrates is generally 20 to 30 g/L.

Waterfowl that ingest unreacted phosphorus can also be killed. Laboratory studies (Burrows et al., 1973) have shown that levels of 3 mg/kg of body weight were lethal to ducks after 6 to 33 hours.

It is not expected that any of the testing at the Devil's Washbasin site will be performed near any aquatic systems where unreacted, elemental phosphorus could potentially contaminate the system.

2. Terrestrial Systems

The available data concerning the toxicity of white phosphorus to terrestrial organisms have been produced from research conducted by the Army, but this research has only been concerned with laboratory mammals (Brown, 1980). Of these mammals, guinea pigs appeared to be the most sensitive, with lethal inhalation levels of phosphorus smoke at concentrations of 4,000 to 5,000 mg/minute/m^3. Rats and dogs were able to survive inhalation of phosphoric acid at more than 20 times the concentration that was lethal to guinea pigs. Among other animals, deaths due to inhalation have been recorded from concentrations as low as 100 mg/m^3 (White and Armstrong, 1935). For most species, however, the critical concentration for the LC_{50} is close to 2500 mg/m^3. These exposures were 15-minutes long, however, and the tests at Devil's Washbasin will last for 1 hour.

The atmospheric concentrations of WP/FW smoke would be, even at a range of 100 m downwind, much less than the concentrations found to be toxic to laboratory animals. Because of the human activity, it is not expected that any wildlife at the test site would approach within 100 m of the test area.

Chronic effects of sublethal exposure of laboratory animals to phosphorus smoke have been studied (Fleming et al., 1942). These animals developed an abnormal thickening of bone tissue. However, it is not expected that the testing of WP/FW at Devil's Washbasin will occur frequently at one location.

This will reduce the possibility of chronic exposure of the smoke products to the wildlife of the area.

However, the inhalation of phosphorus smokes can cause severe throat irritation, and skin contact can cause burns and destroy underlying tissue (Wasti et al., 1978). Acute phosphorus toxicity has two stages. The initial stage is gastrointestinal irritation with vomiting. The second stage may result in death from cardiovascular collapse (Dacre et al., 1979). Animals could receive lethal doses of elemental phosphorus if they ingest unreacted smoke materials. These effects could result, however, only from the small amount of unreacted phosphorus left after the test.

The deposition of phosphoric acid on the vegetation of Devil's Washbasin can be determined by using the foliar retention formula. This formula is the NSC value times the velocity of the smoke materials times the concentration of aerosols.

The NSC value is the Chamberlain "normalized specific concentration". The value is 30 to 60 m^2/kg dry weight of foliage. This means that 30 to 60 mg of smoke material would be retained by one kilogram of plant dry matter for every mg of smoke material fallout per m^2 of ground area per day. In the case of soil depositions based on data from Yon et al. (1983) discussed previously, at 100 m downwind:

$$525.6 \text{ mg/m}^2 = 15770 \text{ to } 31540 \text{ mg/kg dry foliage.}$$

E. HUMAN ACUTE AND CHRONIC EFFECTS OF ONE OR MORE TESTS

The occupational health risks of testing smoke products should be assessed. Health effects can be either acute or chronic.

1. Acute Effects

Acute effects are those that reach a crisis rapidly, such as burns, respiratory distress, and headaches. It will be necessary to assess the health effects of both the initial smoke product and the reaction products.

E. HUMAN ACUTE AND CHRONIC EFFECTS OF ONE OR MORE TESTS

1. Acute Effects

Human sensitivity to toxic materials is highly variable. Because of this, there is a concentration range rather than a cutoff point for exposure to toxic materials. Animal deaths have occured from inhalation of as little as 100 mg/m^3 of phosphorus smoke, although the LC_{50} for most species is close to 2500 mg/m^3. There is no reason to expect that the human reaction would be different than the reactions of animals.

The smoke generated from WP/FW is a complex mixture of phosphine, phosphorus, phosphorous acid, and phosphoric acid, and evaluating the toxicity of such a complex mixture is difficult. Each of the reaction products of phosphorus smoke is identified as an irritant; each will cause an inflammatory reaction at the point of contact. The duration, potency, and point of contact will all affect the response. Severe reactions can result in skin burns and irritation to the nose, throat, lungs, skin, eyes, and mucous membranes.

Phosphorus burns can cause severe local and systemic injury and can be accompanied by fluid and electrolyte imbalances and infection. The local injury is caused by the burning phosphorus and the production of phoshoric and phosphorous acid. The absorption of toxic quantities can have acute effects on the liver and can be accompanied by vomiting and weakness.

The site of pulmonary deposition is dependent upon particle size. A high level of humidity will result in a larger particle of WP smoke. Therefore, it has been suggested (Task Group on Lung Dynamics, 1966; Chan et al., 1980; Wolff et al., 1979) that any phosphorous trioxide or phosphorous pentoxide that is inhaled into the humid atmosphere of the upper respiratory tract would increase to a size too large to be inhaled into the lungs themselves.

A medical report that detailed the accidental 15-minute exposure of humans to WP smoke described severe respiratory symptoms, including necrosis of bronchial epithelium, edema of the larynx and vocal cords, cough, and sputum production. In addition, there were some lower respiratory tract symptoms. After eight months, one of the victims was still unable to speak effectively (Walker et al., 1945).

There have been suggestions (Berkowitz et al., 1981) that inhalation exposures longer than 15 minutes to concentrations higher than 2,000 mg/m^3

would result in human death. The longer the duration of exposure at each concentration, the greater number of fatalities could be expected. There are currently no data that can predict safe and unsafe exposure times or concentrations.

2. Chronic Effects

Chronic effects are those that reach a crisis over an extended period of time, such as cancer, bone deterioration, and anemia. The health risks of both the smoke products and the reaction products should be assessed.

2. Chronic Effects

a. Carcinogenicity. A carcinogen is a cancer-causing substance. There are very little data about the cancer risk posed by phosphorus smokes. For most solid tumor cancers and some types of leukemia, however, the latency period is thirty years. Because of this, most studies dealing with human cancer risks must be long-term studies. Therefore, an absence of positive data does not mean an absence of risk.

There are major data gaps in studies concerning the composition of phosphorus smokes and human health effects due to intermediate and long-term exposure to the smoke. There have been no long-term studies done on the carcinogenicity of WP/FW smoke. Human exposure data are concerned only with very brief, non-lethal exposures, and there are no data relating exposure levels of phosphorus vapors or phosphorus compounds with disease incidence in humans. In past studies, the latency period was highly variable and ranged from 10 months to 18 years.

b. Non-Carcinogenic Effects. Jaw necrosis, known in the past as "phossy jaw," is the principal manifestation of chronic exposure to phosphorus compounds. The association between phosphorus and necrosis of the jaw was first noted in Europe in the nineteenth century among workers employed in the manufacture of phosphorus-based matches. Today, occupational risk from phosphorus exposure is greatest to those frequently exposed to phosphorus smokes.

The vapors of elemental phosphorus, the phosphorus oxides, and the acids of phosphorus are considered to be toxic with chronic exposure to small

amounts. In addition, because arsenic is normally found in the phosphate rock from which WP is prepared, it has been suspected of being a co-factor for risk.

The fact that the maxillary bones are the ones principally affected by chronic exposure to small amounts of phosphorus has suggested that the unique vulnerability of these bones to infection from the teeth and gums has been the most likely risk factor. Long-term chronic exposure can also cause changes in the long bones, and seriously affected bones may become brittle and subject to spontaneous fractures. It can also have an adverse effect on the teeth.

Long-term absorption, particularly through the lungs and gastrointestinal tract, can cause chronic poisoning. This may result in a generalized form of weakness with anemia, loss of appetite, gastrointestinal weakness, and pallor. It has been suggested, however, that these changes may be due to the destruction of the jawbone and the resultant inability to eat and receive adequate nutrition (Heimann, 1946).

VII. ENVIRONMENTAL CONSEQUENCES OF THE PROPOSED ACTION

After the impacts of the tests have been identified, they should be explained and assessed. This evaluation is based on the significance of each impact, its reversibility, and the direct, short-term, long-term, and cumulative effects of each impact.

The significance of the impacts of the tests on the environment in terms of quality of life must be described. This will include predictions of impacts on air, water, soil, ecological systems, and other aspects of the environmental setting.

VII. ENVIRONMENTAL CONSEQUENCES OF THE PROPOSED ACTION

To adequately assess the impact of the smokes and their reaction products on the environment of the test, and to protect the natural resources of the site, geographic limits to the downwind concentrations of hazardous materials were established (Fig. 16). These boundaries were established by running simulations using the HAZRD2 model, and by using results from previous tests, air quality standards, data on wind speed and direction, a

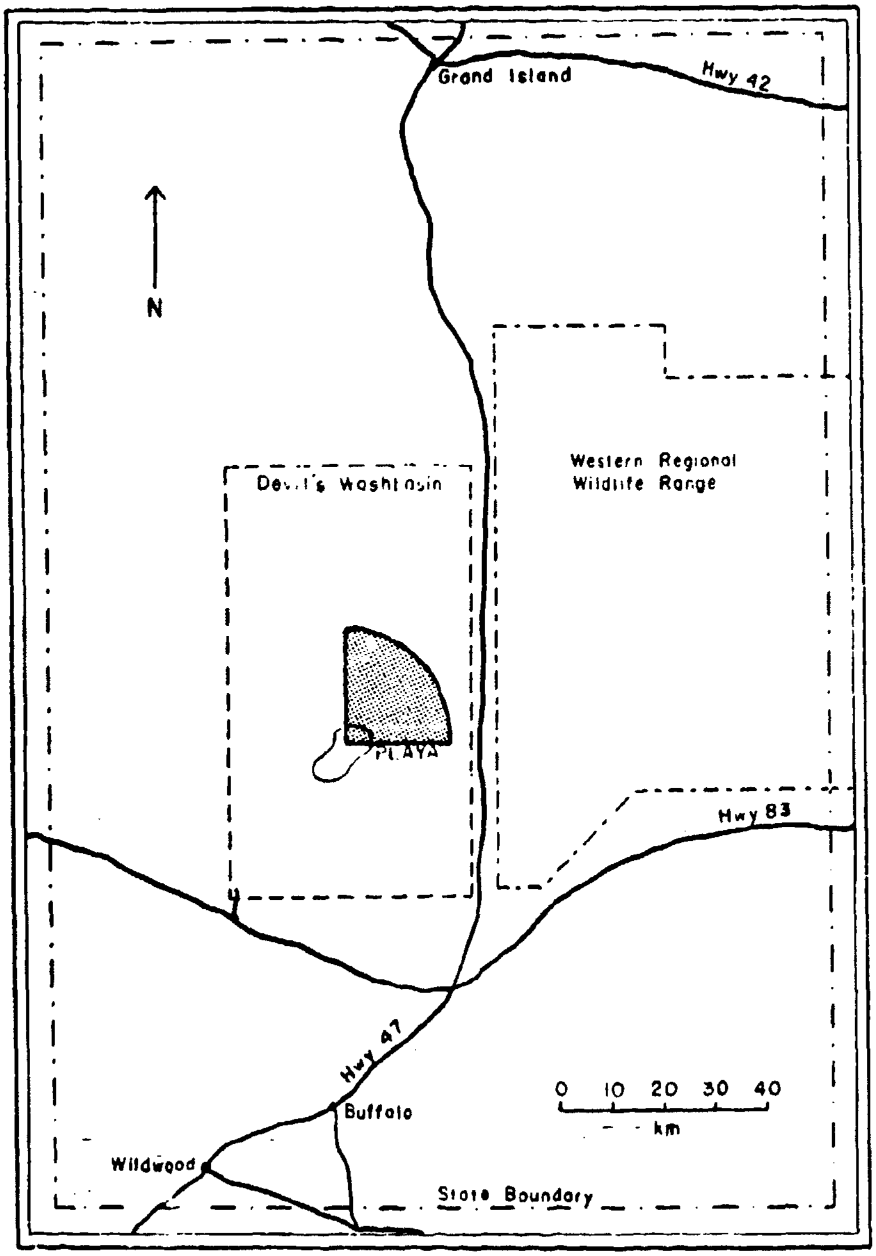

Figure 16. Impact zone and downwind boundary for smoke tests at Devil's Washbasin.

trajectory analysis, and Army operational procedures.

Since the Devil's Washbasin test site is not inhabited by human beings, the proposed tests are not expected to have a significant impact on the quality of life in the area.

Primary impacts would include burned vegetation, an introduction of plant nutrients into the environment, and the effect of the smoke cloud on air quality. The phosphoric acid produced from the tests will be transformed in the environment and, because of this, the solubility may decrease more than thirty times in the long term. This rapid transformation will have a tendency to render the reaction products of the WP/FW relatively harmless to plant and animal life in the area. It is not expected that any impacts of the tests will be irreversible or permanent.

A. AIR QUALITY

Because the proposed test area at Devil's Washbasin is approximately 75 km north of the community of Buffalo and 90 km northeast of the town of Wildwood and the prevailing wind direction is from the southwest, it is unlikely that ambient concentrations of the major air pollutants from the tests will have any significant impact on the air quality in the region.

All of the proposed testing will meet the state and federal air quality standards for the major pollutants and general ambient-air emission guidelines. The standards will not be exceeded at any point to which the public has access or at any other location outside of the geographic boundaries of the test site.

In addition to the initial smoke cloud from the test, there may be additional smoke produced by burning vegetation. If necessary, a state burning permit will be obtained.

B. WATER QUALITY

None of the smoke tests are expected to have an impact on water resources at the Devil's Washbasin site. Groundwater is located 200 m under an impervious layer underneath the playa. Grand Island Creek is located 35 km downwind of the test site and is not expected to receive any significant fallout from the tests. Standing water on the playa during the rainy season

will receive fallout, but the high solubility of phosphoric acid will render the impacts relatively harmless.

C. LAND USE

US Army and US Air Force operations at Devil's Washbasin could be potentially affected by the testing of WP/FW at the site. Coordination between the different branches and their training exercises will be necessary and monitoring stations will have to be established. Mitigation will be required to protect personnel from exposure to harmful concentrations of hazardous materials.

Special consideration will be given to the possibility of range-fire and the potential impact of fire danger will be mitigated if necessary.

D. SPECIES AND POPULATIONS

The primary impacts to animal populations in the area would be the result of ingestion of either unreacted phosphorus or vegetation on which phosphoric acid has been deposited. This impact is expected to be of relatively little significance. Those animals most likely to be affected would be coyotes, migratory waterfowl, lizards, snakes, rodents, and black-tailed jackrabbits. In summer, burrowing species most likely will not be affected by the smoke cloud because they plug the entrance to their burrow during the day.

E. COMMUNITIES AND HABITATS

Since there are no threatened or endangered species within the test area at the Devil's Washbasin site, no habitats of these species would be destroyed. The *Atriplex* association at the edge of the playa is of concern, however. This vegetation supports a large variety of wildlife and if it is burned or contaminated by phosphoric acid, numerous habitats could be disrupted or destroyed.

F. ECOSYSTEMS

The high solubility of phosphoric acid will render it of little significant impact to the ecosystems of the Devil's Washbasin site.

G. ACCIDENTS

There is always the possibility of an accident when working with hazardous materials. In general, for hazardous conditions to exist with the testing of WP/FW, it will be necessary for high smoke concentrations and troops to be in the same area at the same time. The following types of accident are foreseeable.

1. Leaks of Phosphorus from the Shell

Leaks of phosphorus from the shell can be caused by vibration or shock during transport or handling. Troops handling the shells may receive burns. Prompt first aid should always be available. If indoors, potentially toxic concentrations of phosphorous oxides could be released, but it is unlikely that field testing would require the use of indoor space.

2. Incorrect Deployment

Premature deployment can be caused by a short fuse, and deployment on friendly troops can be caused by improper assessment of the target. In either case, troops would be exposed to the concentrated smoke cloud. While these accidents are unlikely, the greater danger from a short fuse would be the hazard from exploding shrapnel. Rapid dilution in large volumes of air would help to disperse harmful concentrations of WP smoke.

3. Respiratory Protection Is Not Worn or Fails

Accidents involving respiratory protection would also result in troops' being exposed to potentially harmful concentrations of WP smoke. Rapid dilution in large volumes of air would help to disperse harmful concentrations of WP smoke.

4. Deposition of Unreacted Phosphorus in the Environment

If testing occurs frequently in one area, harmful amounts of unreacted phosphorus from the tests may be deposited in the environment. It will be

necessary to move the testing site frequently to allow the recovery of natural resources and limit the amount of residual deposited in any one area.

5. Local Communities Exposed to the Smoke Cloud

Exposure of local communities would be caused by an unprecedented and drastic change in wind direction and other meteorological conditions. Testing will be conducted in an area where community exposure is highly unlikely.

VIII. CUMULATIVE, LONG-TERM EFFECTS OF REPEATED TESTS

The testing of smokes and obscurants will occur repeatedly at most of the installation sites. It will be necessary to determine the effects that repeated testing will have on the environment.

VIII. CUMULATIVE, LONG-TERM EFFECTS OF REPEATED TESTS

The testing of WP/FW at the Devil's Washbasin site will occur on a weekly basis for a one-hour period per week. This will result in an accumulated deposition of the smoke materials and residual at the test site.

The testing of WP/FW will release reaction products directly into the air and soil, and water systems can be a sink for the products. The main products emitted will be phosphoric acid and phosphorous acid. These products will be rained out and deposited on land and any nearby aquatic systems. In soil, they will be converted to phosphates that will, in turn, be taken up by plant systems and incorporated into the ecosystem. Unreacted phosphorus residuals can have toxic effects in concentrations as low as one part per billion (ppb). The spent munition casing, ash, and organic phosphorus will be deposited at the site of ignition.

The testing of WP/FW at the Devil's Washbasin site is intended to create a steady-state smoke screen. This will result in an atmospheric phosphoric acid concentration of 3100 mg/m^3 averaged over the plume above 516 m^2 of ground area. This concentration of phosphoric acid will be high enough to inhibit both visible and infrared radiation at relative humidities greater than

50%. To maintain this obscuring concentration of smoke for one hour, deployment of 7 to 72 M2 shells would be required.

It has been estimated that more than 60% of the white phosphorus residual will remain in the wedges (Davis et al., 1984). It is expected that the remainder of the unreacted white phosphorus will be oxidized upon contact with the soil or soil solution. Some vegetation will be burned with the oxidation. The most harmful impact resulting from the accumulation of white phosphorus is deposition in aquatic systems; however, this will not be a problem with the Devil's Washbasin site.

The levels of phosphoric acid in the peak atmospheric concentration of smoke have a potential for only minimal acute mammalian exposure. A concentration level of 146 mg/m^3 is approximately a factor of 10 smaller than the inhalation LC_{50} for the most sensitive mammalian species tested (Yon et al., 1983). However, some sublethal effects on mammals, such as irritation of the eyes and trachea, are expected. Because of this potential for harmful effects to wildlife at the test site, it is recommended that the test area be moved each week.

IX. SHORT-TERM USE OF THE ENVIRONMENT VERSUS EFFECTS ON LONG-TERM PRODUCTIVITY

A. UNAVOIDABLE ADVERSE IMPACTS

Risks to the biological communities in the area of the tests will be, to a large extent, unavoidable. It will be necessary to assess and evaluate these risks and develop mitigation strategies to minimize their impacts.

IX. SHORT-TERM USE OF THE ENVIRONMENT VERSUS EFFECTS ON LONG-TERM PRODUCTIVITY

A. UNAVOIDABLE ADVERSE IMPACTS

Some risks to the biological communities at Devil's Washbasin will be, to a large extent, unavoidable. Even when the testing is conducted with the recommended mitigation measures, some potential adverse impacts will need

to be considered. The testing will require the release of potentially hazardous materials into the atmosphere and soil of Devil's Washbasin. The amounts involved, however, will be relatively insignificant. It has been observed, as well, that some species of wildlife, such as birds and deer, will leave the area during the test and return afterwards (Muhly, 1983).

It is possible that small areas of natural vegetation downwind of the ignition site could suffer temporary injury. There is also a possibility of vegetation loss at the edge of the playa. There are no federally listed rare, threatened, or endangered plant species that could be adversely affected.

There is a small risk of death or injury to a few individuals of certain wildlife species that may be present in the area of the ignition. It is unlikely, however, that any healthy wild animals would approach human activity at a close range. No federally listed rare, threatened, or endangered animal species are at risk within the test area.

Testing should be conservatively managed to allow recovery of wildlife and vegetation.

The testing of phosphorus smokes will have several short-term environmental effects. Vegetation in the area of the test will be burned but should be able to grow back within a month. If the vegetation does not grow back, there will be a potential for soil erosion. With atmospheric concentrations of 3100 mg/m^3 averaged over the ground area of 516 m^2, most of the phosphorus in the smoke will oxidize to forms that are relatively insignificant in the environment. Only with repeated use of the test site could there be a potential for a toxic or nutritive impact on the vegetation of the area. Since the Devil's Washbasin area has not been used for human productivity since the nineteenth century, the primary concern would be for biological productivity. It does not appear that impacts would be significant.

The potential for acute, lethal mammalian exposure would also be minimal. Except for the most sensitive laboratory species (guinea pigs and mice), the atmospheric concentrations of phosphorus smoke, even within 100 m of ignition, are well below the concentrations that cause death. There would undoubtedly be some non-lethal, reversible adverse effects on any mammals in the immediate vicinity of the test. There have not been any studies done to determine the effects of phosphorus smoke on reptiles, amphibians, or other non-mammalian organisms.

B. RESTRICTIONS OF LAND USE OPTIONS

The Devil's Washbasin site has been selected specifically for the use of smoke testing. Military land use options would not be affected by the tests.

X. ALTERNATIVES AND RECOMMENDED MITIGATION MEASURES

Alternatives to the proposed tests and/or mitigation measures for the proposed tests must be identified and evaluated. Each alternative should enable the accomplishment of similar goals but will have a different or less severe environmental impact. The alternatives can include modifications to the tests, moving to another site, and the alternative that must always be considered--no project.

X. ALTERNATIVES AND RECOMMENDED MITIGATION MEASURES

There are three alternatives to the proposed action: no project, conduct the tests at another location, and conduct the tests indoors. These alternatives are presented in Table 8 and are discussed below.

A. ALTERNATIVES

1. No Project

With this alternative, no environmental impacts would occur. Smoke testing is necessary, however, to accurately predict the behavior of smoke clouds and to determine the effectiveness of the obscurant in maintaining national security.

2. Conduct Tests at a Different Location

Moving the testing to another location would insure that no environmental impacts would occur at the Devil's Washbasin site. Based on data from the Department of the Army, 10 installations were selected as being most suitable for smoke testing. These sites were selected on the basis

TABLE 8. ALTERNATIVES TO PROPOSED TESTING.

Alternative	Smoke Residual at Devil's Washbasin	Smoke Residual Elsewhere	Trained Troops
Proposed Action	X		X
No Project			
Different Location		X, environmental impact may be worse	X
Conduct Indoor Tests		X	

of their remote location and their relative capacity for minimal environmental impacts. Therefore, moving the test to another location would not insure that environmental impacts would be minimized.

3. Conduct Testing Indoors

While laboratory conditions can produce valuable data, they cannot simulate actual field conditions. To produce this field data, it will be necessary to conduct the tests outdoors.

B. MITIGATION MEASURES

In evaluating the potential environmental impacts of WP/FW at Devil's Washbasin, the following mitigation measures would considerably reduce or alleviate potential harmful impacts.

1. Restrict Time of Testing

In addition to testing under US Army operational procedures, the testing should be restricted to daylight hours, midmorning to late afternoon, between the months of March and September. Maximum test periods should be no more than one hour in duration.

2. Begin Tests on a Small Scale

Testing should begin with small tests to more accurately predict the fate of the smoke cloud. These small tests should confine the cloud to the geographic area of the playa. The minimum amount of smoke mix to achieve an obscuring concentration should be used.

3. Submit an Operations Plan

An operations plan will be submitted for all tests. This plan will cover all aspects of the proposed tests and will insure compliance with the installation Environmental Assessment. This plan would address cleanup of the site as well as the responsibilities for performing various tasks, such as choosing and

running dispersion models and conducting environmental and safety surveys. Cleanup, evacuation, and safety procedures would be studied and a review of necessary permits will be completed.

4. Provide Dental Examinations

All personnel who might potentially come into contact with the phosphorus smoke cloud should have a thorough dental exam. Personnel should have no existing dental caries or gingival disease.

5. Relocate Test Sites Frequently

Test sites should be moved after each test to lessen potential environmental impacts.

6. Conduct Tests Away from Water

Tests should not be conducted near any body of water. Concern should also be given to the potential for leaching into groundwater supplies or runoff into surface aquatic systems.

7. Follow Regulations on Hazardous Materials for Cleanup

Cleanup of the test site should be conducted according to regulations for handling hazardous materials. This would apply especially to felt wedges, which may still contain unreacted WP.

8. Keep Proper First-Aid Materials at Hand

First-aid designed specifically for the treatment of phosphorus burns should be on hand at all times. In the p t, a 5% solution of copper sulfate was applied to phosphorus wounds while awai. . g debridement and dressing. A recent study (Summerlin, 1967), however, indicates that the copper may be toxic as well, and may result in massive hemolysis. A current, conservative approach to the treatment of phosphorus burns would not include the

application of copper sulfate to the wound. Procedures that will minimize skin contact with the smoke mix should be established.

9. Use Proper Safety Devices

Safety devices, including hearing protection devices, thick gloves, safety goggles, and gas masks should be worn at all times by personnel conducting the tests.

10. Notify Other Agencies

Appropriate installation agencies should be notified. These include, but are not limited to, the Air Pollution Control Authority, the Post Fire Department, the Post Forester, and the airfield control tower.

11. Establish an Effective Communication System

A communication system between the smoke operators and headquarters should be established to more effectively monitor the smoke cloud.

12. Monitor Test Area for Erosion

The area of the test site should be monitored for soil erosion if it appears that extensive vegetation will be burned.

XI. RECOMMENDATION FOR A FINDING OF NO SIGNIFICANT IMPACT

If it is clear from the material presented in the EA that the environmental effects will not be significant, it is proper to make a recommendation that a finding of no significant impact be made. The recommendation need not be lengthy and may refer to mitigation measures that will be taken to prevent any significant effects.

XI. RECOMMENDATION FOR A FINDING OF NO SIGNIFICANT IMPACT

The analyses in this assessment show that the effects on the environment from this proposed action will not be significant. The testing will be restricted to wind conditions that will minimize the effects. Furthermore, the test locations will be relocated frequently so that potential impacts will be lessened. Consequently, it is recommended that a finding of no significant impact (FNSI) be made.

XII. REFERENCES

The references presented here are references used in the sample sections of this volume. They are presented as examples of a reference style. In an actual EA, references should be used extensively to document the facts.

XII. REFERENCES

Patton, S. E., M. G. Novo, and J. H. Shinn, 1986. *Environmental Assessment for LGF Spill Test Facility at Frenchman Flat, Nevada Test Site,* **Lawrence Livermore National Laboratory, Livermore, CA, UCID-20716-1986.**

Shinn, J. H., S. A. Martins, P. L. Cederwall, and L. B. Gratt, 1985. *Smokes and Obscurants: A Health and Environmental Effects Data Base Assessment, A First-Order, Environmental Screening and Ranking of Army Smokes and Obscurants,* **Lawrence Livermore National Laboratory, Livermore, CA, UCID-20931.**

Yon, R. L., R. S. Wentzell, and J. M. Bane, 1983. *Programmatic Life Cycle Environmental Assessment for Smoke/Obscurants, Vol. 2, Red, White and Plasticized White Phosphorus,* **Munitions and Chemical Command, Chemical Research and Development Center, Aberdeen Proving Ground, MD, ARCSL-EA-83002, AD-A135 910.**

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